INTRODUCTORY ENVIRONMENTAL NOISE

COURSE MANUAL

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and development of the course material contained herein.

Head, Noise Assessment Unit:	L.G. Kende, MASc., P. Eng.
Editor-in-Chief and Project Co-ordinator	C.A. Krajewski, MSc., P. Eng.
Contributors:	C. Chiu, P. Eng. R. Krawczyniuk, MSc. R. Ramakrishnan, PhD., P. Eng. V. Schroter, PhD.

ABSTRACT

The present publication is a reference manual for the training course "Introductory Environmental Noise". The purpose of the course is to familiarize the trainees with environmental noise problems, and the basic qualitative and quantitative methods of noise assessment.

The document covers the following topics: Basic Acoustics, Measurement of Sound, Analysis of Community Noise, Environmental Noise Criteria, Prediction of Road Traffic Noise, Overview of Noise Control By-law, Investigation of Stationary Source Noise Impact, Industrial Noise and Blasting and Noise Complaint Investigation Procedure.

RÉSUMÉ

La présente publication sert de manuel de référence au cours d'introduction au bruit environnemental intitulé «Introductory Environmental Noise». Ce cours se propose de familiariser les stagiaires aux problèmes du bruit environnemental et aux méthodes qualitatives et quantitatives fondamentales permettant d'évaluer le bruit.

Sujets traités : acoustique fondamentale, mesure du bruit, analyse du bruit dans une localité, critères d'évaluation du bruit environnemental, prévision du bruit de la circulation routière, aperçu des règlements régissant la lutte contre le bruit, enquête sur les effets du bruit en provenance d'une source fixe, bruit dû à l'usage industriel d'explosifs, et, enfin, méthodes d'enquête sur les plaintes à propos du bruit.

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CHAPTER 1

ACOUSTICS

1.0 NATURE OF SOUND WAVES

1.1 Description of Sound

If a person claps his hands, or strikes a hammer or plays a violin, sound is produced. Sound is an auditory perception of a disturbance which travels or propagates in the form of waves similar to waves in water.

For the sound to travel or propagate the surface must be in contact with a material medium such as air, water or a solid. Sound cannot propagate in vacuum.

A familiar sight is waves travelling across the surface of water. The action of the water particles is simply to bob up and down like a cork and not to move with the wave. In sound waves the particles of the medium simply oscillate to and fro in the direction of the wave, but again do not actually travel with the wave. The energy in the wave is transferred to more distant parts of the medium by a "chain" reaction.

1.2 Sound Pressure

Consider a loudspeaker generating sound as shown in Figure 1.1. It does so by the to and fro motion of a diaphragm which in turn transmits this motion to the air adjacent to it. This results in small fluctuations in air pressure which travel outwards. These fluctuations in pressure are picked up by the ear as sound. Note that

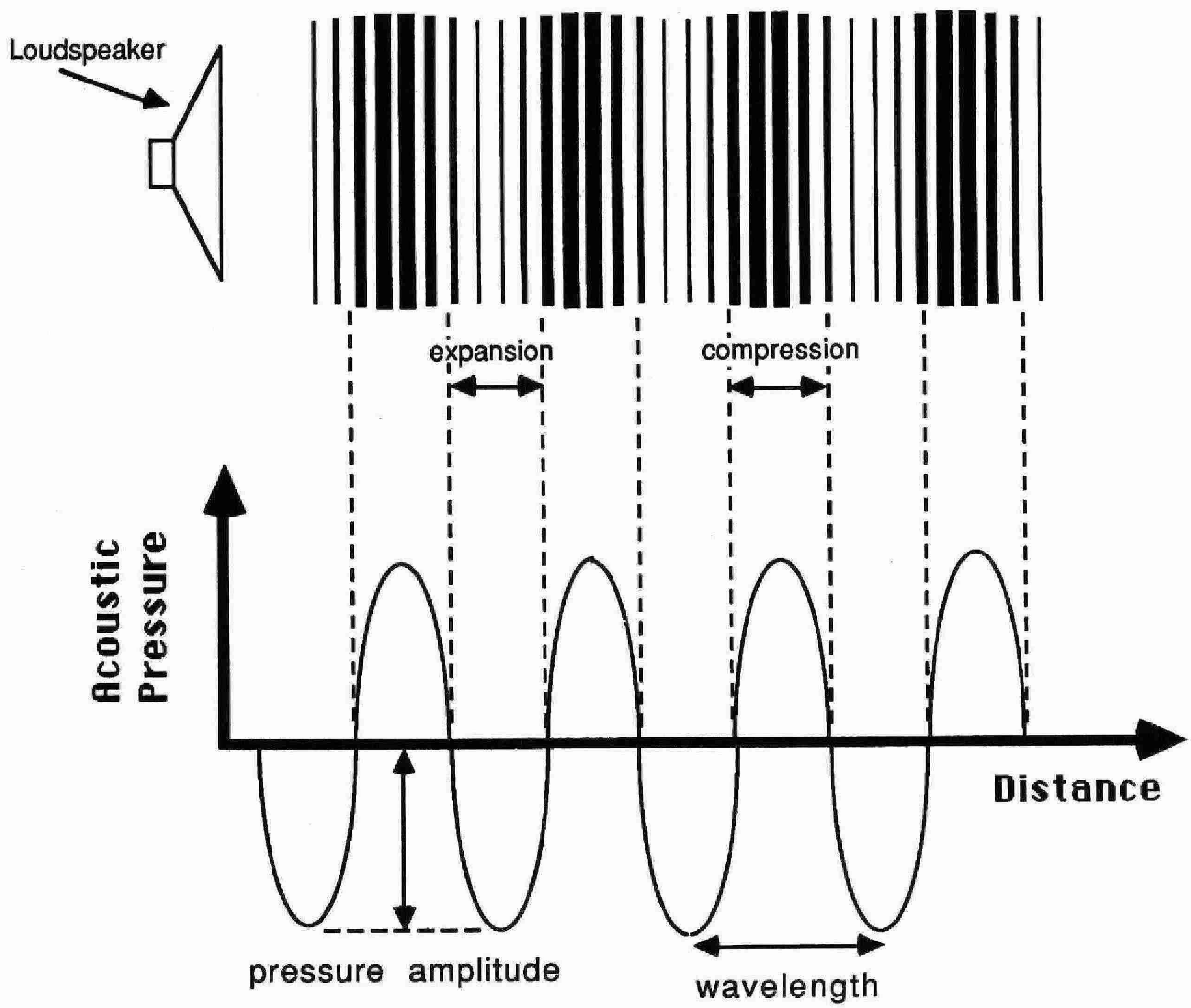


Figure 1.1. Generation of sound waves

this pressure fluctuation due to sound is superimposed on the normally existing barometric pressure. The additional pressure due to sound is very small compared with the normal barometric pressure.

This to and fro motion causes alternate compression and expansion of the air. These pressure fluctuations are sensed by the ear as sound.

1.3 Speed of Sound in Air

Sound waves do not travel instantaneously. Their speed depends on the medium through which they travel. The speed of sound in air is related to atmospheric temperature, and at 20°C the speed of sound in air is approximately 344 m/sec.

Example

Although lightning and thunder are generated simultaneously during a thunderstorm, the observer first notices the lightning and only later hears the thunder. The delay is caused by the time needed for the sound to travel from the thunderstorm location to the observer. (The light due to the lightning can be considered to travel the distance almost instantaneously.)

1.4 Sound Power

Sound power is a basic measure of the acoustic output of a noise source. The sound pressure produced by the source depends on many external factors such as distance and orientation of the receiver, the temperature and velocity gradients in the medium and the environment. Sound power on the other hand is a fundamental physical property of

the acoustic source alone and is, therefore, an important absolute parameter which is widely used for rating and comparing sound sources.

Sound power is expressed in "watts".

2.0 FREQUENCY, WAVELENGTH AND SPEED OF SOUND

2.1 Frequency

Consider the earlier example of the loudspeaker (refer to Figure 1.1). When the diaphragm of the loudspeaker moves to and fro this generates pressure fluctuations in the air adjacent to it in the form of sound waves.

The number of times every second the air experiences these pulsations or fluctuations is known as the "frequency of the sound waves".

Obviously the frequency of the sound waves generated is the same as the frequency at which the diaphragm moves to and fro.

The frequency of sound waves is expressed in "cycles per second". Cycles, in this case, refer to the pulsations of air due to sound waves. In noise control work a more commonly used unit is "hertz" (Hz). "Cycles per second" and "hertz" are the same.

Example

If the loudspeaker diaphragm moves to and fro 125 times every second continuously, the frequency of sound waves thus generated will be 125 cycles per second or 125 Hz.

All sounds can be related in terms of frequencies. Generally most of the every day sounds are a mixture of different frequencies, and the human ear is capable of detecting sounds in the approximate frequency range 15 Hz to 15,000 Hz (or 15 kHz). The ear's sensitivity is not uniform or "flat" over this range, the sensitivity reducing rapidly at the extremes of the frequency range. The sensitivity of the ear to frequency plays an important role in the noise control field.

2.2 Wavelength

The distance between to successive waves is defined as the wavelength. When we talk about the wavelength of a sound wave, we refer to the distance between two successive points, where either the compression or the expansion is maximum (also indicated on the diagram, Figure 1.1). Wavelength is not usually directly measured but can be determined as shown in the following section.

Wavelength can be calculated from a knowledge of the frequency and the speed of the sound. It is given by the following relationship:

$$\text{wavelength} = \text{speed of sound}/\text{frequency} \qquad (1.1)$$

If the speed of sound is expressed in metres per second, and the frequency in Hertz, the wavelength will be in metres.

Example

In air, the speed of sound at 20°C is 344 m/sec.

For a frequency of 100 Hz:

wavelength in metres = 344/100 = 3.44 m

For a frequency of 500 Hz:

wavelength in metres = 344/500 = 0.688 m
= 68.8 cm

It is to be noted that the sound frequency increases as wavelength decreases.

When measuring sound in the immediate vicinity of sound sources outdoors, a knowledge of wavelength helps in selecting the best measurement locations. The distance between measurement location and the source should ideally be much larger than the wavelength corresponding to the frequency of interest. At the other extreme, high frequency sound (having a short wavelength) is not directly measurable when the diameter of the microphone exceeds the wavelength of the sound. The latter is an example of diffraction of sound, the ability of sound to "bend" around obstacles. The amount of this bending is again related to wavelength, bending increasing with wavelength. This subject is treated in Chapter 9.

3.0 TYPES OF SOUND WAVES

As explained in the previous sections, sound travels in the form of waves. There are basically three types of sound waves:

- o Spherical
- o Cylindrical
- o Plane

The type of wave generated depends upon the sound source. The sound waves from a loudspeaker at a distance of about 15 m will be of the spherical type. On the other hand, when we think of the noise from freely flowing traffic on a highway, the noise comes from a very large number of (moving) point sources. It can be shown that the sound from a whole string of point sources gives rise to waves which spread in a cylindrical fashion, the line or string of sources, being the axis of the cylinder. At very large distances from a source (very large in comparison to the size of source) spherical and cylindrical waves are very similar to plane waves and may be considered as such. Examples of spherical and cylindrical waves are shown in Figure 1.2.

4.0 LOGARITHMIC SCALE: DECIBELS

4.1 <u>Range of Sound Pressure Values</u>

The ear can respond to an amazingly wide range of acoustic pressures. In everyday life we may encounter acoustic pressures such as generated by rustling leaves and the acoustic pressures of a roaring jet engine. The acoustic pressure of the latter example may be one million times that of the former. In between these two extremes lie all the familiar sounds of modern life, e.g. traffic, bird songs, roadworks, etc.

While we have discussed acoustic pressure and the response of the ear to it, experience has shown that the square of the pressure is a fundamentally more useful quantity in assessing the magnitudes of sounds. The major reason for this is that the square of the pressure as measured at an observer is related to the acoustic power of the noise source.

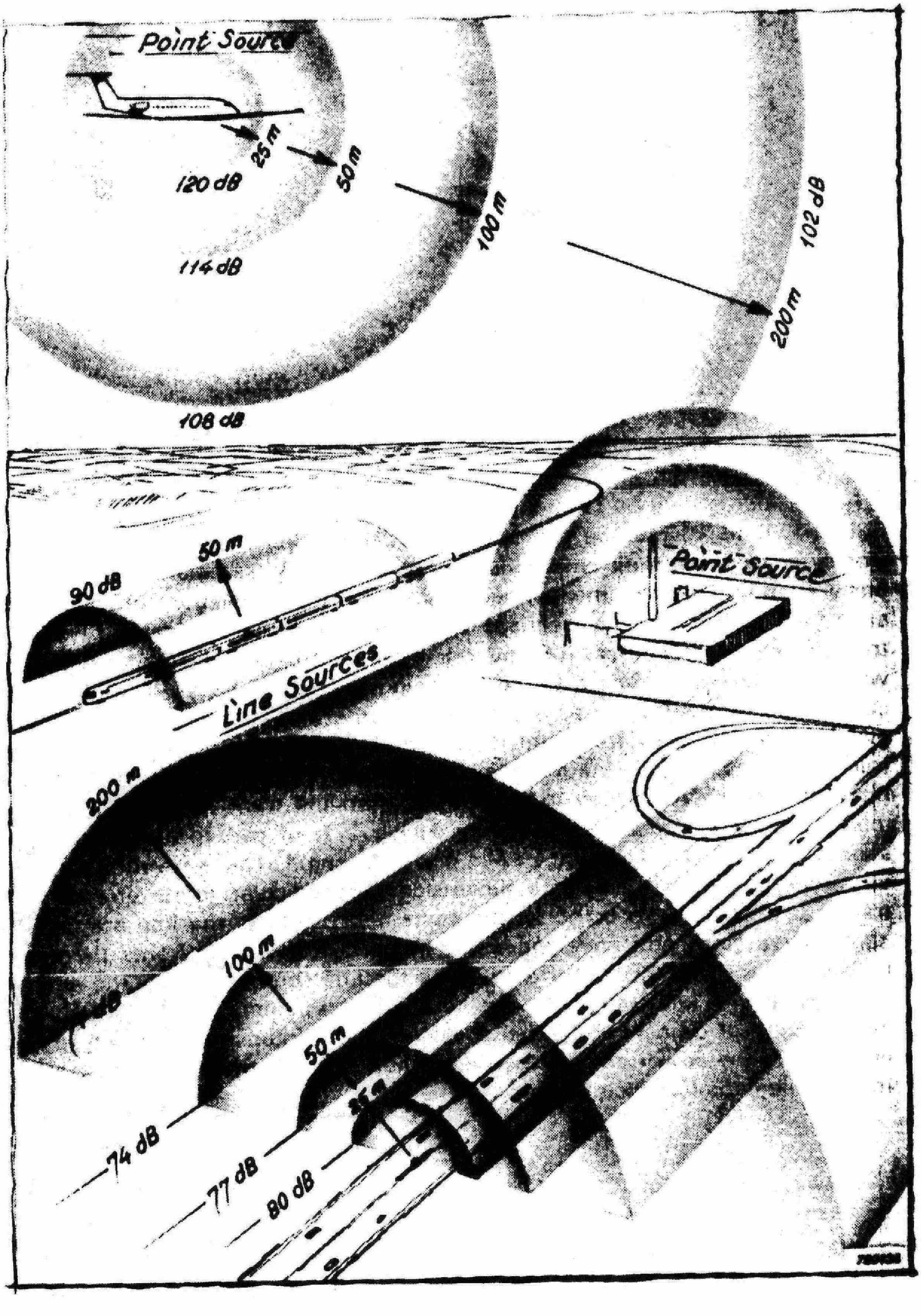


Figure 1.2. Examples of point and line sources

4.2 Decibel Definition

Another reason for adopting "pressure squared" term is that this naturally leads to the use of the decibel scale of measurement. The decibel scale is widely used in various branches of electronics and acoustics. The decibel scale is a power scale and gives a comparison between power related quantities. When quantities are compared using the decibel scale, the comparison is referred to as a Level.

Definition

The Sound Power Level (PWL) or L_W, of a noise source is defined as:

$$L_W = 10 \log [W/W_{ref}] \quad \text{dB} \tag{1.2}$$

where W is the acoustic power output of the source in watts, and W_{ref} is the standard reference power of 10^{-12} watts. In all likelihood W will be greater than the very minute value chosen for W_{ref} and so all sound power levels will be a positive number of dB's.

Also, the square of the acoustic pressure is related to the acoustic power output so we may now define SPL, or L_P, at some observer as:

$$L_P = 10 \log [P^2/P^2_{ref}] \quad \text{dB} \tag{1.3}$$

where, P is acoustic pressure of the sound waves, in microPascals, µPa and P_{ref} is the standard reference pressure of 20 µPa, which corresponds to the threshold of hearing.

4.3 Relationship Between SPL and PWL

The PWL is a measure in decibels of the sound power output by a source. This sound power will radiate away from the source in all directions. As the sound waves travel away from the source the pressure fluctuations must decrease because the available sound power is being spread over a larger area (see Figure 1.2).

A similar situation exists when a balloon is being blown up. The bigger the balloon becomes the more the rubber is obliged to stretch and the thinner it becomes. The sound pressure fluctuations are "diminished" and reduced in a similar manner as the available sound power is spread over a larger and larger surface area. The sound power output itself remains constant whatever the distance from the source. The sound pressure fluctuations decrease according to the area over which the available sound power has been spread. Thus the relationship between the sound pressure level, L_P, and the sound power level, L_W, in most simple situations can be expressed as follows:

$$L_P = L_W - 10 \log S \qquad (1.4)$$

where, S is the total surface area in m^2, over which the sound power is spread. We can now take this equation further for the two main types of source.

4.3.1 Point Source

A point source can be imagined as being a point suspended in space radiating sound equally in all directions. Let us consider an observer at a distance r from this point source of sound power W with no reflecting surfaces present.

First, $S = 4\Pi r^2$ (i.e. the area of a sphere of radius r). Let us also consider the effect of increasing r on the sound pressure level.

Let L_{P_1} be the Sound Pressure Level at distance r_1

and L_{P_2} be the Sound Pressure Level at distance r_2

Then $L_{P_1} = L_W - 10 \log [4\pi r_1^2]$

$$L_{P_2} = L_W - 10 \log [4\pi r_2^2]$$

$$L_{P_2} - L_{P_1} = 10 \log [4\pi r_1^2] - 10 \log [4\pi r_2^2]$$

Thus, for a point source

$$L_{P_2} - L_{P_1} = 20 \log [r_1/r_2] \qquad (1.5)$$

From this equation it can be seen that if the distance from a point source is doubled, the sound pressure level is reduced by 6 dB.

4.3.2 <u>Line Source</u>

A line source can be imagined as an infinitely long line suspended in space radiating sound equally in all radial directions. A similar procedure can be followed as for a point source to obtain the relationship between sound power level and sound pressure level for a line source. However, this involves integration techniques and will not be considered here. Only the effect of increasing r on sound pressure level will be considered.

Again let

L_{P_1} be the sound pressure level at distance r_1

and L_{P2} be the sound pressure level at distance r_2.

Thus, for a line source

$$L_{P2} - L_{P1} = 10 \log [r_1/r_2] \qquad (1.6)$$

From this equation it can be seen that if the distance from a line source is doubled the sound pressure level is reduced by 3 dB.

Example

A sound level of 65 dB was measured at 10 m distance from a line source. The sound level at 30 m is required.

Let L_{P1} = 65 dB measured at r_1 = 10 m

then from equation 3.6 (for a line source)

$$\begin{aligned} L_{P2} - L_{P1} &= 10 \log [r_1/r_2] \\ L_{P2} - L_{P1} &= 10 \log (10/30) \\ &= -4.8 \text{ dB} \\ L_{P2} &= 65 - 4.8 \\ &= 60.2 \text{ dB} \end{aligned}$$

4.4 Advantage of the Decibel Scale

The decibel scale is commonly used in electronics and acoustics for the measurement of power related quantities.

An advantage of the decibel scale is that the unwieldy numbers which result from using a linear pressure scale are replaced by a much smaller range.

Another feature of the scale is that for each and every tenfold increase in power, the SPL at an observer increases by 10 dB. If we should increase the power output from 10^{-12} W to 10^{-11} W or from 1 W to 10 W we would, in each case, get an increase of 10 dB. Although the actual change or absolute change in power output in the two cases is quite different, we get the same change in decibels. This is actually of value because if we listened to these changes in level, approximately the same subjective response would be obtained - we would say that in each case the noise had doubled in loudness from its former value. That is, the increase in loudness appears the same.

The sound pressure levels and sound power levels of various types of common noise sources are shown in Figures 1.3 and 1.4.

4.5 <u>Weighting Networks</u>

It was pointed out in Section 2.1 that the ear's response to sound is not linear over the audible frequency range (15 Hz - 15,000 Hz). In addition, the ear's response depends on the sound level.

In order to satisfactorily describe human perception and response to sound, the sound is usually filtered or weighted across the audible frequency range in a manner analogous to spectral response characteristics of the ear. The characteristics of weighting networks that are currently in use are shown in Figure 1.5. The commonly used weighting network in noise measurements is the A-weighting. The sound pressure level after being weighted by the A-network is commonly referred to as dBA. (If the sound pressure levels are taken using linear response characteristics, the values are quoted in dB.)

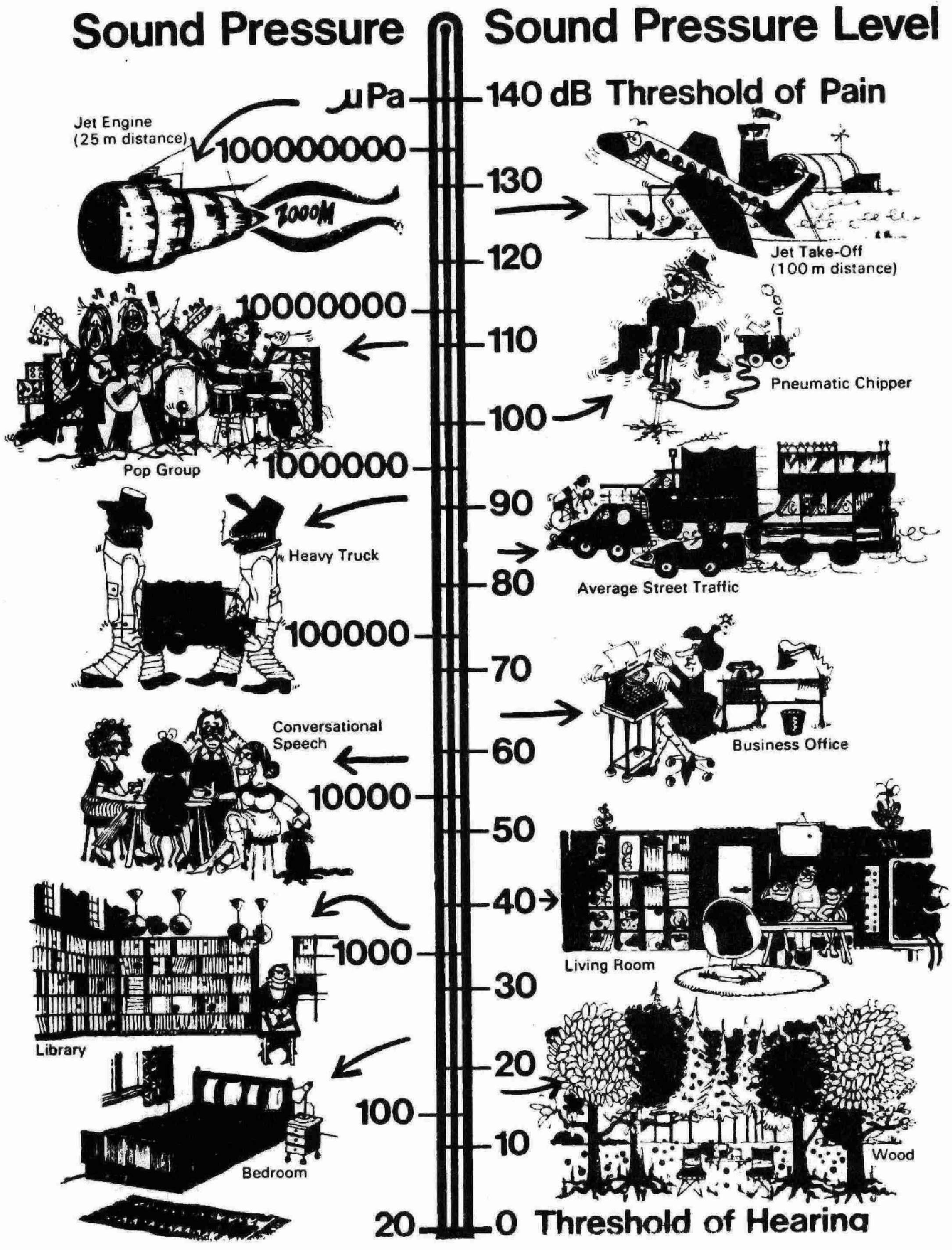


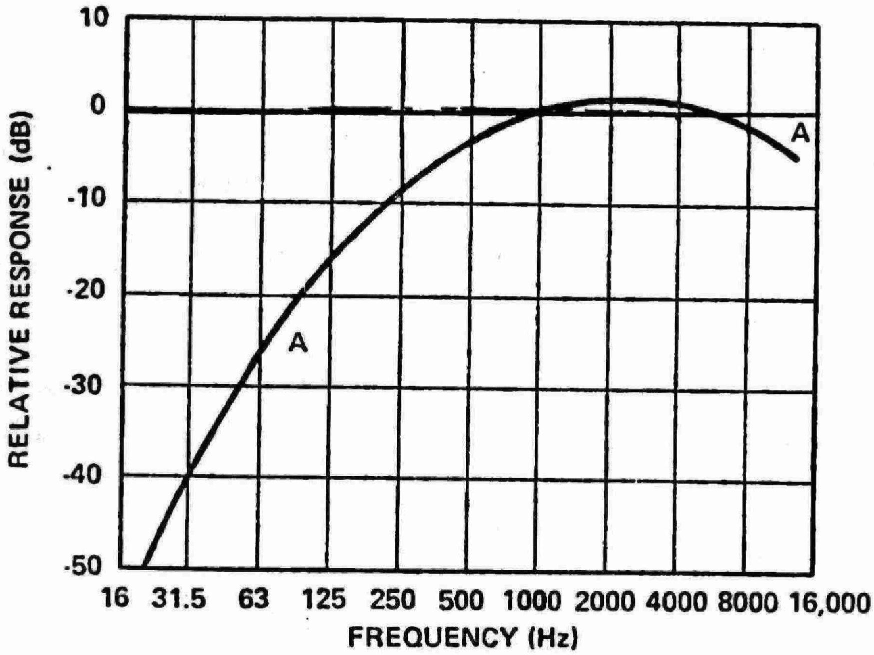
Figure 1.3. Typical sound pressure levels (SPL)

DECIBELS (PWL)

(reference 10^{-12} watt)

195	Saturn Rocket
170	
	Turbo-jet with afterburner
160	Turbo-jet 35 kN thrust
150	
	4-Propeller airliner
140	
	75-piece orchestra
130	Pipe organ
	Small aircraft engine
120	
	Large chipping hammer
	Piano
	Blaring radio
110	Centrifugal ventilating fan (6500 L/sec)
100	Loom (1m wide)
	Auto on highway
90	Vaneaxial ventilating fan (750 L/sec)
	Voice-shouting
80	
70	Voice-conversational level
60	
50	
40	
	Voice-very soft whisper
30	

Figure 1.4. Typical sound power levels (PWL)



OCTAVE FREQUENCY BAND (Hz)	A-WEIGHTED FILTER RESPONSE (dB)
31	-39
63	-26
125	-16
250	-9
500	-3
1000	0
2000	+1
4000	+1
8000	-1

Figure 1.5. The internationally standardized A-weighting curve

4.6 <u>Sound Level Meter</u>

Sound pressure levels of common noise sources can be conveniently measured with an instrument called a sound level meter. Details of acoustic instrumentation are presented in Chapter 3.

Briefly, a simple sound level meter measures the "linear sound pressure level" in dB and the "A-weighted sound pressure level" in dBA. It also uses two averaging time weighting characteristics: fast and slow.

4.7 <u>Adding Sound Pressure Levels in Decibels</u>

SPLs cannot be added rather they must be combined. This is because when sounds from separate sources are received simultaneously the ear responds to the sum of

their individual power contributions and not to the sum of their pressures (or sound pressure levels in dB). Therefore, as we are usually given the SPL of each source in turn (in dB), conversion to pressure squared terms must be done first. This involves finding the antilog of 1/10 of the SPL. Ten times the logarithm of the sum of such antilog terms gives the resultant SPL of the combined levels. In mathematical notation:

If sound pressure level due to Source 1 is L_{P_1}

If sound pressure level due to Source 2 is L_{P_2}

If sound pressure level due to Source N is L_{PN}.

Then it can be shown that the resultant SPL, L_{PR} is;

$$L_{PR} = 10 \log [\text{antilog} [L_{P_1}/10] + \text{antilog} [L_{P_2}/10] + \ldots + \text{antilog} [L_{PN}/10]] \quad (1.7)$$

This expression may be used to combine the SPLs due to two or more sources, etc.

4.7.1 <u>Addition of Decibels - Nomograph Method</u>

The nomograph given in Figure 1.6 provides a quick, simple and practical method for combining pairs of decibels. The steps involved are outlined below:

<u>Step 1</u>: Take the difference in decibels between the two levels which are being added together.

<u>Step 2</u>: Enter this difference on the chart at the right hand side of the scale, and look up the corresponding number on the left hand side of the scale.

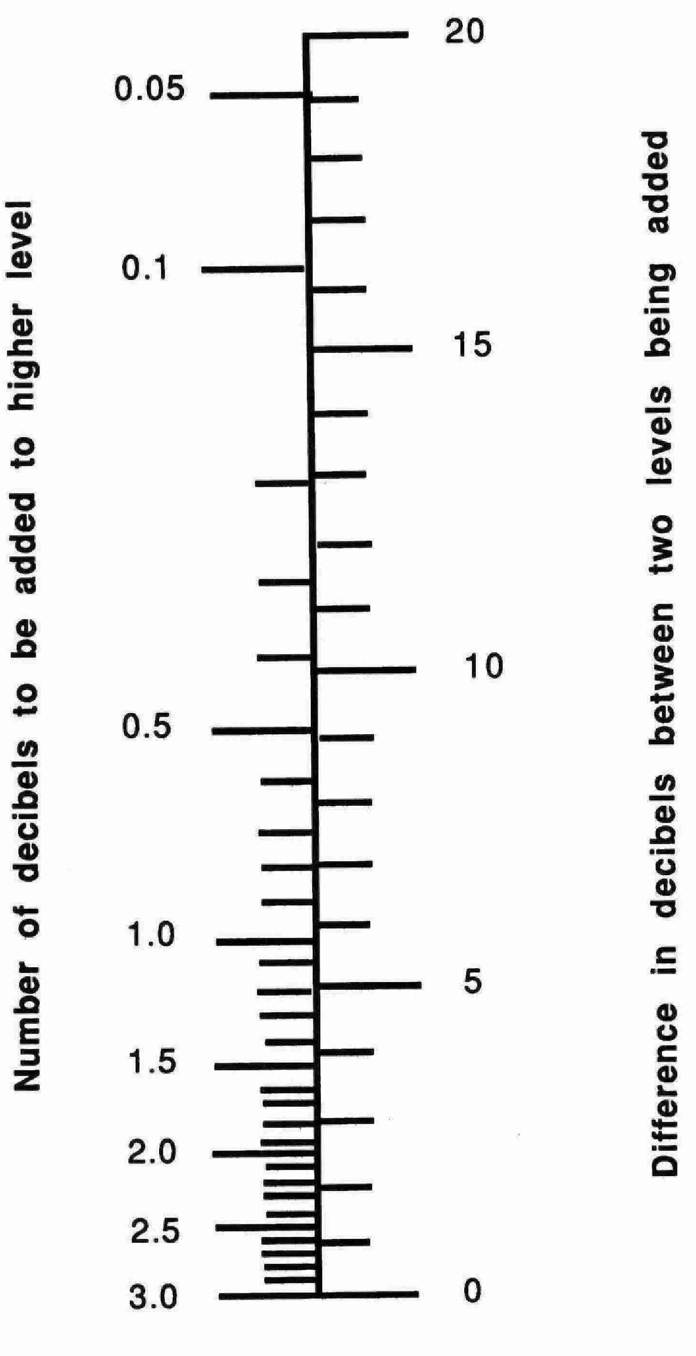


Figure 1.6. Nomograph for adding sound pressure levels in decibels

<u>Step 3</u>: Add the number so obtained to the higher sound level (louder sound of the two).

Should more than two SPLs need to be combined, then any two levels can be replaced in the summation by their equivalent found by the combination process.

<u>Example</u>

Find the resultant of the following sound pressure levels 60 dB, 54 dB and 65 dB.

Consider first 60 dB and 54 dB.

Step 1: the difference is 6 dB
2: from the chart the corresponding number is about 1 dB
3: adding 1 to the higher SPL we get 61 dB

So the result of combining 60 dB and 54 dB is 61 dB. Consider now combining 61 dB (i.e. 60 dB and 54 dB) and 65 dB.

Step 1: the difference is 4 dB
2: from the chart the corresponding number is about 1.5 dB
3: adding 1.5 dB to the higher we get 66.5 dB

So the effective SPL due to the three individual SPLs is 66.5 dB.

Should the sequence in which the SPLs are combined be changed, the identical result would be obtained.

Note from the nomograph method:

(a) two levels will not result in more than 3 dB adjustment to the higher level;

(b) when two levels are more than 10 dB different, their resultant SPL is less than 0.5 dB greater than the higher of the two levels; and

(c) very roughly, for quick calculations, you may use:

difference between two levels, dB	add to higher level, dB
10	0
6	1
2	2
0	3

which can be memorized and interpolations made by constructing a graph.

CHAPTER 2

ANALYSIS OF COMMUNITY NOISE

1.0 INTRODUCTION

The assessment of noise impact of proposed projects or actions necessitates the acquisition of a number of critical pieces of information. The different pieces of information are used in judgements and decisions regarding associated costs versus benefit, the degree of noise control desired and the feasibility of noise mitigating techniques. In the field of community noise analysis the required information is usually centred around the physical attributes of sound.

The main objective of noise analysis is to relate the physical attributes of the noise environment to measures of human response or criteria of acceptability. Many of the physical attributes and measures of sound were outlined in the previous chapter. The useful relationships between the physical exposure and noise impact are usually obtained by measurements, computation and by the use of various noise descriptors. A noise descriptor is a physically measurable quantity such as Sound Pressure Level in dB and the descriptor is used to scale the impact numerically.

The community noise impact can be described by a variety of descriptors. One such descriptor is presented in this chapter. The rationale for choosing the descriptor, the definition of the descriptor and its applications are also presented.

2.0 THE TIME VARYING NATURE OF COMMUNITY NOISE

Many community noise sources do not produce noise of a steady nature. Noise sources such as traffic, construction sites and radios produce noise levels which are time-varying, often between very wide limits. The fluctuating nature of the community noise is evident in a continuous record of the sound level as illustrated in Figure 2.1. The figure represents a time history, i.e. the sound levels are recorded as a function of time.

In any typical community, the lower noise levels will be present for a major portion of the time and will consist of natural sounds such as leaves rustling, flowing water, bird or animal noises. These noises are often accompanied, or perhaps dominated, by distant traffic noise or steady industrial noise. The next higher noise levels will be present a shorter duration and be generated by such sources as nearby highways and industry. Increasing again in level, and decreasing in duration, local traffic would contribute next to the sound pattern. Trucks and trains would have higher levels but are present only for short periods of time. Sources generating even higher levels are children shouting, dogs barking and even thunder, all of which are fortunately only present for very short periods of time. It is, of course, difficult to generalize the sound level variation with time in a community, but it can be judged from the example given that, as the sound level increases, then it is present for shorter periods of time. This trade-off relationship between level and time duration is generally typical of most community noise situations.

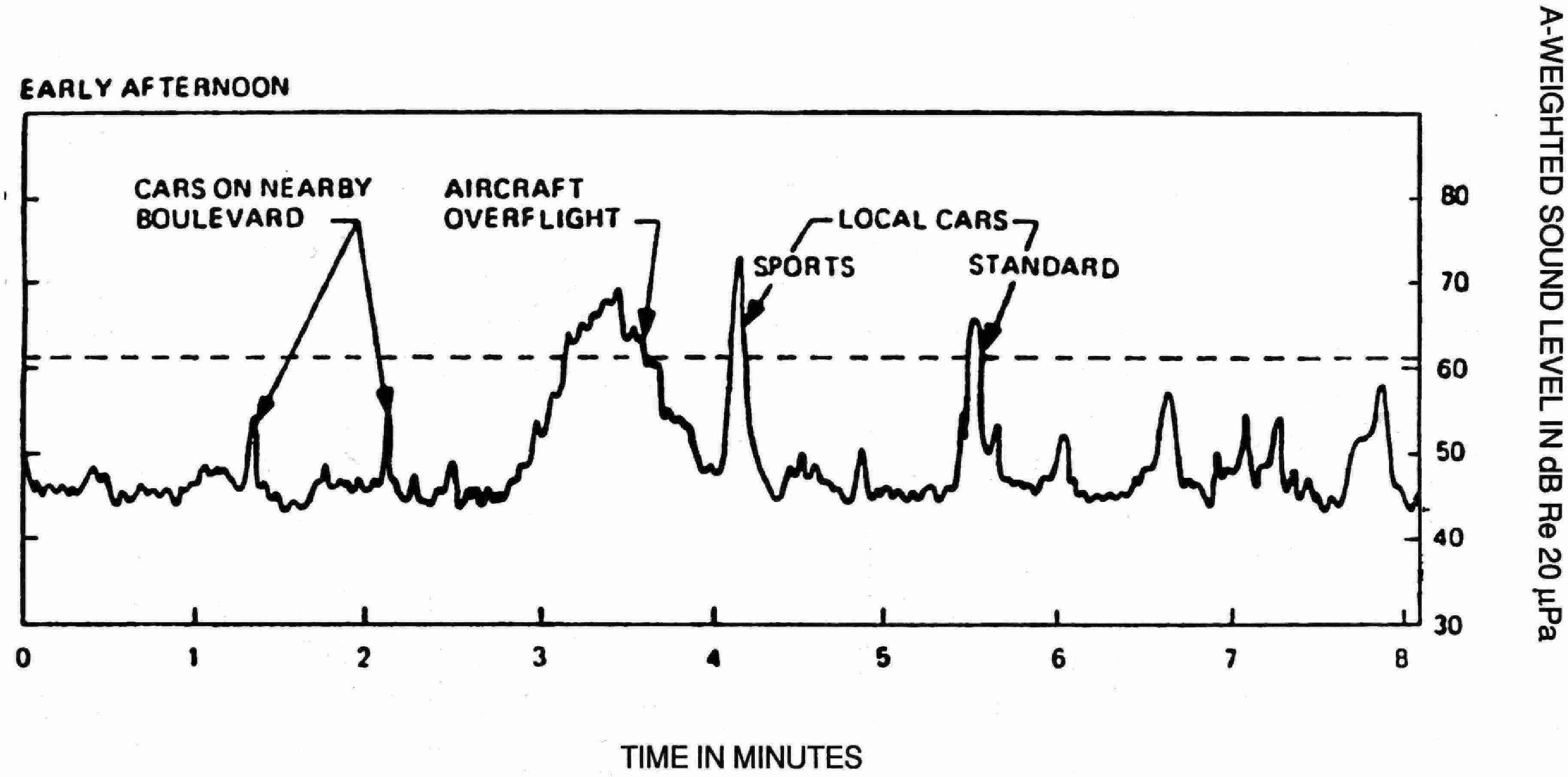


Figure 2.1. Representative graphic time history of sound level as sampled in an urban area. Dashed line represents equivalent energy concept.

2.1 Range of Variation in Community Noise Levels

To give some idea of the possible variation of community noise levels with time consider the two extreme situations; in the first case the community is located adjacent to a busy freeway and at all times the noise climate is dominated by the free flowing traffic. Typical variation in the community noise level is 10 to 20 dB.

At the other extreme, consider the situation of a small community situated close to railway tracks. At night with no train passbys the noise level in the community may be very low, typically 25 to 30 dBA in quiet surroundings. However, as a train passes by the noise levels could increase up to 90 dBA. This gives a sound level range of some 60 dBA. Specialized instrumentation may be required if acoustic measurements are to be conducted.

2.2 The Limitations of the Sound Level Meter for Community Noise Measurement

It was pointed out earlier that community noise levels vary from 10 to 60 dB between quiet and noisy periods, depending on the type of noise source. A simple sound level meter is usually not sufficient to measure such unsteady noises. If a sound level meter needle shows a range of deflections greater than 3 dB, then a single, eyeball-average sound level will not accurately reflect the noise environment. Many community noise situations will produce deflection ranges greater than 3 dB, making the simple sound level meter unsuitable for community noise measurement.

A further problem may occur because most sound level meters can only measure sound levels that have a range of 10 to 15 dB. Even though a sound level meter may be

suitable for community noise analysis its limited scale range does restrict the use of the instrument.

2.3 Using a Sound Level Meter to Obtain a Series of Community Noise Measurements

The simple sound level meter can be used for the assessment of non-steady community noise by taking single sound level measurements at certain regular intervals (say 10, 20 or 30 seconds) over a specified measurement duration. Assume that a sound level meter was used close to a busy highway, where the variation is only 10 to 20 dB. Noise level readings were taken at exactly 10 second intervals for 10 minutes, resulting in 60 single sound level measurements. The results were rounded off to the nearest A-weighted decibel and entered into the following chart in Figure 2.2, each box representing one sound level reading.

The chart provides a useful picture of the whole variation of the noise level over the ten minute period. The noise level never fell below 65 dBA. The noise level was steady for a long time at 70 dBA, this level probably being associated with individual car passbys.

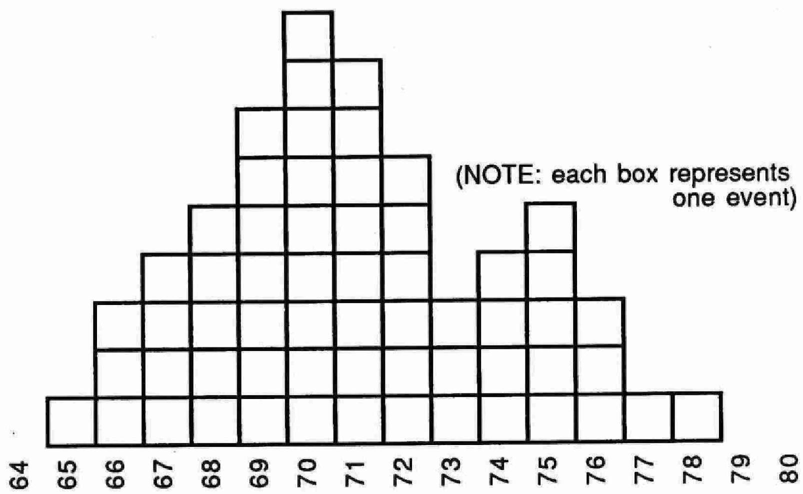


Figure 2.2. Typical histogram of sound level measurements adjacent to a freeway

A second peak occurred at a sound level of 75 dBA which probably represents individual truck passbys, which would be less frequent than the cars, but at a higher noise level. The maximum sound level recorded was 78 dBA. Thus the chart provided a useful picture of the noise variation over the 10 minute period. Such a chart is known as a histogram, and is a diagrammatic representation of the statistical distribution of the sound variation during the specified time period.

3.0 STATISTICAL SOUND LEVELS

Although time histories such as the one shown in Figure 2.1 are quite illustrative, a more convenient way to describe fluctuating environmental noise is to adopt a purely statistical approach that takes into consideration the total time or proportion of time the sound of interest is present at various specific levels.

The time varying sound level data can be represented in the form of a histogram (a sample is shown in Figure 2.2) or a cumulative distribution curve, each of which denotes levels of noise which are exceeded for given percentages of the time over given periods of observation, or, conversely, the proportion of time certain noise levels are exceeded. The relevant statistic is generally expressed as a noise level, L_N, which is exceeded for N percent of the time. An example of a statistical distribution of time-varying urban noise is concisely illustrated in Figure 2.3.

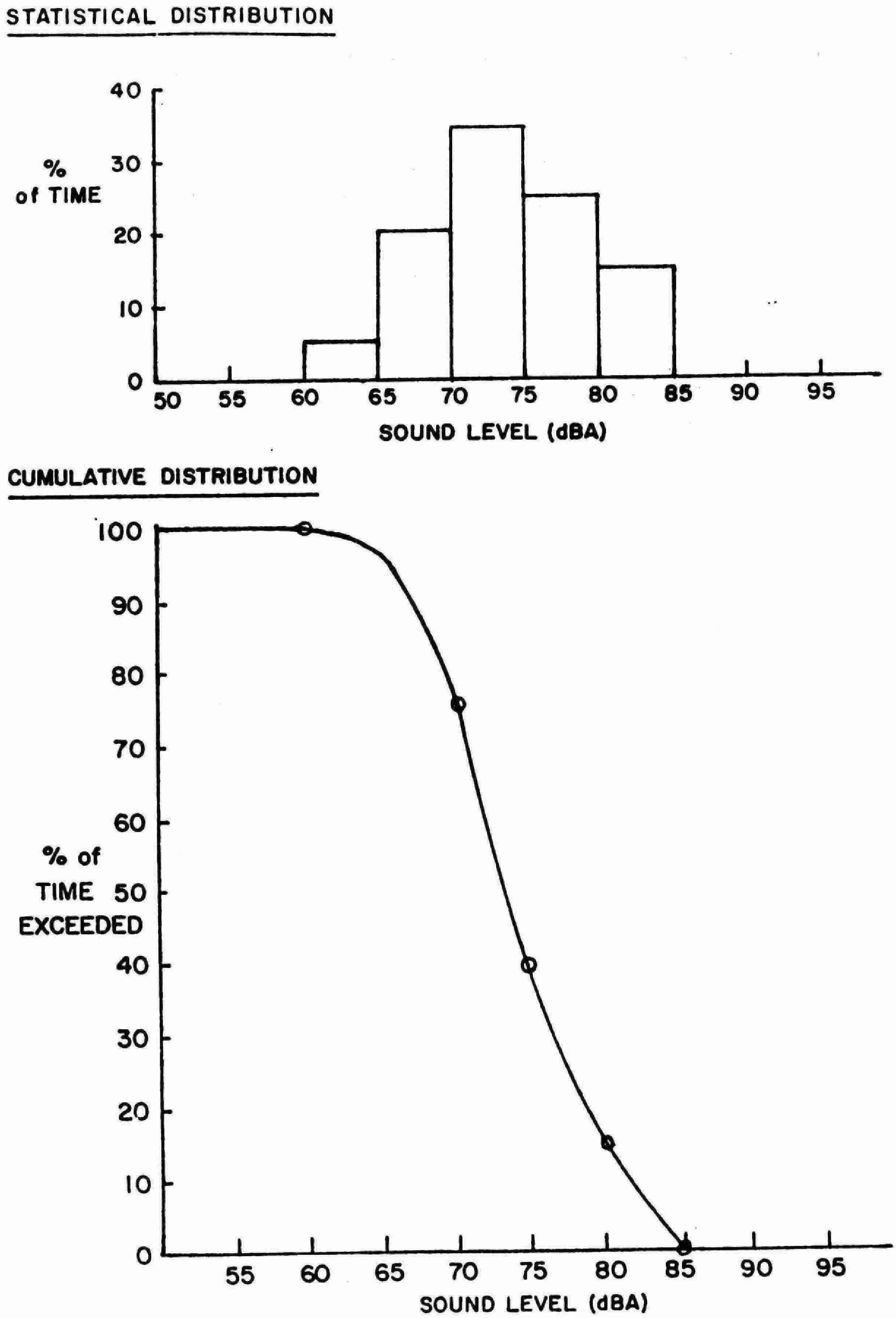


Figure 2.3. Generation of cumulative distribution plot from statistical distribution plot.

4.0 DEFINITIONS AND USE OF L_N, L_{100}, L_{90}, L_{50}, L_{10} and L_0

We have just seen that a cumulative distribution is a plot of the percentage of time for which certain sound levels were exceeded. In order to extract useful information from the plot, very often the reverse question "What level was exceeded for a certain percentage of the time?" is presented. For instance, it may be required to know what level was exceeded for 10% of the time? Looking at the plot on statistical distribution paper, we see that the level exceeded for 10% of the time was 82 dBA. Such levels are often known as L_N values, L_N being defined as follows:

- L_N is the level exceeded for N% of the time.

  Common L_N values used are as follows:

- L_{100}: the level exceeded for 100% of the time or the lowest noise level.

- L_{90}: the level exceeded for 90% of the time or an indicator of the "ambient" noise level.

- L_{50}: the level exceeded for 50% of the time or the "medium" noise level.

- L_{10}: the level exceeded for 10% of the time, measures the "average level of intrusive" noises.

- L_0: the level exceeded for 0% of the time or the "highest" noise level (also known as L_{max}).

By convention L_{90}, L_{50}, and L_{10} are used in common practice to represent approximate measures of background, median and intensive noise levels respectively. These statistical values form the basis of many environmental noise rating methods.

4.1 Derivations of Percentile Levels from Cumulative Distribution Graph

The percentile levels can be obtained from the cumulative distribution plot. Specific values of six most common descriptors taken from the graph in Figure 2.3 are:

L_N	Sound Level dBA
L_{100}	60
L_{90}	67
L_{50}	74
L_{10}	81
L_1	84
L_0	85

5.0 CONCEPT OF THE ENERGY EQUIVALENT CONTINUOUS LEVELS

For many years acousticians have searched for a method of describing time varying sounds by a single number rather than by the entire cumulative distribution or certain L_N values obtained from such a distribution.

In order to assess time-varying noises, the unsteady sound level (still measured in dBA) could be averaged in some way to provide a steady level which would be "equivalent" to the original varying sound. Considerable research has been done to determine how this averaging should be performed.

Simple averaging of the time-varying pressure of the sound is not a good method of assessing the annoyance of unsteady, intrusive value. This method tends to underestimate the annoyance value. It has been found that if the energy (which is proportional to the square of the pressure) of a time-varying sound is averaged, then the resulting energy equivalent continuous level, Leq, has good correlation with the annoyance of that sound.

For the purpose of certain environmental noise controls, the community noise descriptor, Leq, has been selected. The adoption of Leq does not necessarily preclude the use of other descriptors.

5.1 <u>The Definition of Leq</u>

The energy equivalent level is that constant sound level which has the same energy as a time-varying noise level for a specified time duration. In order to understand fully the concept of Leq it is also necessary to consider the mathematical definition.

$$Leq = 10 \log (1/T) \int_o^T [P_A^2(t)/P_o^2]\, dt, \quad dBA$$

Where P_o = the standard reference pressure

$P_A(t)$ = the A-weighted time varying pressure

T = the measured duration (2.1)

<u>Example</u>:

The noise from a certain machine was measured for a one hour period. The sound levels and the respective time durations were as follows:

78 dBA for 30 minutes
80 dBA for 20 minutes
83 dBA for 10 minutes

(NOTE: the total time of measurement is 60 minutes.) Calculate the Leq value for 1 hour.

First the sound level relationship must be applied to find the pressure squared ratio for each time period.

$$L_A = 10 \log [P_A/P_o]^2$$

$$[P_A/P_o]^2 = \text{antilog } [L_A/10]$$

Thus to determine the pressure squared ratio, each sound level must be divided by ten and antilog is obtained as follows:

78 ÷ 10 gives 7.8, antilog of 7.8 is 6.3×10^7 for 30 minutes.

81 ÷ 10 is 8.1, antilog of 8.1 is 1.25×10^8 for 20 minutes.

83 ÷ 10 is 8.3, antilog of 8.3 is 2.0×10^8 for 10 minutes.

Now, the equation (2.1) can be used to integrate these levels over a 60 minute period.

$$\begin{aligned} Leq &= 10 \log (1/60)[6.3 \times 10^7 \times 30 + 1.25 \times 10^8 \times 20 \\ &\qquad + 2.0 \times 10^8 \times 10] \\ &= 10 \log (1/60)[189 \times 10^7 + 25 \times 10^8 + 20 \times 10^8] \\ &= 10 \log [63.9 \times 10^8]/60 \\ &= 10 \log [1.06 \times 10^8] \\ &= 10 \times 8.03 \\ &= 80.3 \end{aligned}$$

Leq = 80 dBA for one hour

It is interesting to consider the Leq derivation for constant sound level. In this case the averaging process (integration over time T and division by time T) is unnecessary as the average of a constant is that constant. Thus for a constant sound level the equation reduces to exactly the same equation as the definition of dBA, that is for a steady sound:

$$Leq = L_A = 10 \log [P_A/P_o]^2 \qquad (2.2)$$

Thus for a steady sound the Leq value will be the same as the SPL (L_P) value.

6.0 TRADE-OFF RELATIONSHIP OF TIME VERSUS SOUND LEVEL

Leq measurement is always performed for a particular time duration. It is necessary to state the time period for the measurement along with the Leq. If there are two noise sources which are "on" for different time durations, two sources cannot be directly compared by their respective Leq values. One of the Leq values must first be corrected to the same time duration as the other source to allow direct comparison of levels. To be able to do this, a trade-off relationship between sound level and time is used.

The trade-off relationship can easily be derived from the mathematical definition of Leq given in equation 5.1. Let a noise source produce a certain Leq_1 with a corresponding pressure Peq_1 for a time T_1. Consider the effect of taking an Leq measurement over a longer time T_2. Let the value of Leq obtained from this longer test be Leq_2 then:

$$Leq_2 = 10 \log [1/T_2 \int_o^{T_1} [Peq_1/P_o]^2 \, dt, \quad \text{dBA}$$

The pressure Peq_1 need only be integrated over time T_1 as it is "off" for the rest of the time under consideration.

$$\begin{aligned} Leq_2 &= 10 \log [T_1/T_2] \; [Peq_1/P_o]^2 \\ &= 10 \log [T_1/T_2] + 10 \log [Peq_1/P_o]^2 \\ &= 10 \log [T_1/T_2] + Leq_1 \\ &= Leq_1 - 10 \log [T_2/T_1], \text{ dBA} \qquad (2.4) \end{aligned}$$

This relation shows that an Leq value for a certain time duration will always be decreased when the time is lengthened.

The trade-off relation must always be used with care. Before it is used, it is necessary to understand the correct method of extending the result of an Leq measurement to a longer duration. Two situations exist. First, if a short representative sample is taken of a noise source, the Leq value obtained will apply for as long as the source is "on". For times longer than for which the machine is "on", that is time which includes periods when the machine is "off", then the trading relationship must be used. The time during which the source is "off" will reduce the resultant Leq.

6.1 Example of Transforming Measured Leq Values to a Different Time Duration

This transformation can be illustrated through the following example:

Example:

A representative sample of noise was taken for 5 minutes, and the Leq value of 69 dBA calculated. By observation it was found that the source in question was "on" for a total of six hours between 07:00 and 19:00. Calculate the Leq for the day time period (07:00 to 19:00 hours).

Leq for 5 minutes = 69 dBA
Leq for 6 hours = 69 dBA
(machine is "on" for 6 hours)

The Leq for 12 hours (07:00 to 19:00) is required $\therefore T_1$ = 6 hours, T_2 = 12 hours.

Leq = 60 - 10 log (12/6) [refer to equation (2.4)]
= 60 - 10 x log 2
= 69 - 10 x 0.3
= 69 - 3
= 66 dBA for 12 hours

- It should be noted that if the duration is doubled then 3 dBA is subtracted from the measured Leq to give the measured Leq value for the longer time duration.

- Also note that Leq values for 5 minutes and 6 hours are the same since the 5 minute sample was a representative sample of the noise.

7.0 THE TIME DURATION IN COMMUNITY NOISE ANALYSIS

When taking community noise measurements, it is very important to obtain a representative sample. Consider the situation of an industry producing fairly continuous mid-level noise and occasionally performing a venting operation which produces a higher level for a short period of time. In this case, a time period must be used which contains both noise situations, and further, does not . place unequal weight on either situation. To ensure that a representative sample has, in fact, been taken, a considerable time period may have to be analysed. In some cases up to several hours or the entire day, evening or night period are monitored on the site and the results analysed.

7.1 Ministry of the Environment Guidelines

The Ministry uses two sets of procedures to analyze community noise which are outlined below.

7.1.1 For most land use applications the time duration is divided into day/night periods. The daytime is 16 hours in duration from 07:00 hours to 23:00 hours. The night-time is the eight-hour period from 23:00 hours to 07:00 hours. The Leq is required for the 16-hour and 8-hour periods. The details of the procedures will be described in subsequent chapters.

7.1.2 For land use application where the noise source is aircraft flyover noise, the Ministry procedures use noise contours determined using the entire 24-hour period.

For the three different time periods described above, the sound level evaluation either by prediction or by measurements can be limited to a representative one-hour time period if the output from the noise source does not vary considerably. Examples of such sources are road traffic, an industry with repetitive processes, etc.

In summary, one hour Leq analysis will be adequate in most instances as the representative value in each of the three different time periods used by the Ministry.

CHAPTER 3

MEASUREMENT OF SOUND

1.0 INTRODUCTION

In order to quantitatively assess the magnitude of noise impact, it is necessary to measure the sound pressure level. This can be accomplished using a sound level meter which is an instrument consisting of a microphone, an amplifier, weighting filters, and an indicating meter. The microphone converts sound waves into corresponding electric signal which is then amplified and modified in such a way as to provide readings of sound pressure level on the indicating meter. Usually, a control, also called an attenuator, is provided to adjust the range of sound levels that can be read, permitting the meter to be used for measurements over wide range of sound levels.

The electronic filters, such as A, B and C-weighting and frequency band, are incorporated in the sound level meter to assess the effect of noise on people. Usually, the A-weighting is used as its response characteristics corresponds most closely to the response of the ear to most types of environmental sounds. Some sound level meters are also equipped with one-octave or one-third octave-band filters to facilitate analysis of the frequency content of the measured sound.

Sound level meters commonly measure the averaged (the so-called root mean squared, RMS) level of the acoustical signal, and the response of the indicating meter is determined by preselection of one of the meter time weighting characteristics, "Slow" or "Fast". These

characteristics determine the time over which the signal is integrated to provide an averaged reading.

One of the primary differences between various sound level meters is accuracy. Technical standards specify four types of sound level meters:

<u>Type 0</u> - Precision Sound Level Meter - used only for noise and vibration measurements in scientific research and development as well as for noise emission certification.

<u>Type 1</u> - Precision Sound Level meter - used only in carefully controlled field environments or in laboratory work.

<u>Type 2</u> - General Purpose Sound Level Meter

<u>Type 3</u> - Survey Sound Level Meter - rarely used except as a quick check on noise levels.

The use of Type 0 and Type 3 sound level meters is not recommended by the Ministry of the Environment.

To verify the reliability of a sound level measurement, calibration is necessary for each set of data taken. This may be achieved by the use of a calibrator, an accurate sound source which introduces a reference sound level signal into the microphone. The procedure involves placing the calibrator over the microphone and adjusting the sound level meter until the meter reading corresponds to the reference sound pressure level.

There is a great variety of instruments available on the market, and a wide variety of applications to which they may be put.

2.0 REVIEW OF ENVIRONMENTAL NOISE INSTRUMENTATION

2.1 General Purpose Sound Level Meters

Type 2 meters usually use piezoelectric microphones and have an accuracy of at least ±2 dB at 1 kHz. They usually incorporate the A, B and C weighting filters, and allow measurements over a wide range of sound levels. Occasionally, octave-band filters and detachable microphones are also incorporated. Typical examples of Type 2 Sound Level Meters are illustrated in Figure 3.1

The make and type of instruments shown are not necessarily endorsed by the Ministry of the Environment. They simply represent some common types in current use.

2.2 Precision Sound Level Meters

In general, Type 1 meters are used only in carefully controlled field environment or in laboratory work. They have accurate microphones of either the air- or electret-condenser type which may be mounted remotely in order to minimize the effect of the operator and instrument case on the incident sound field. Type 1 meters can measure over a larger range of sound levels than the other two types (Type 2 and 3), and have an accuracy of at least ±1 dB at 1 kHz.

In addition to "Slow" and "Fast" they are also equipped with "Impulse" and "Peak" time-weighting characteristics, which enable measurement of impulse noise such as forging, stamping or gun fire. An overload signal indicator is a common feature for this type of meter.

Typical examples of precision sound level meters in current use are shown in Figure 3.2.

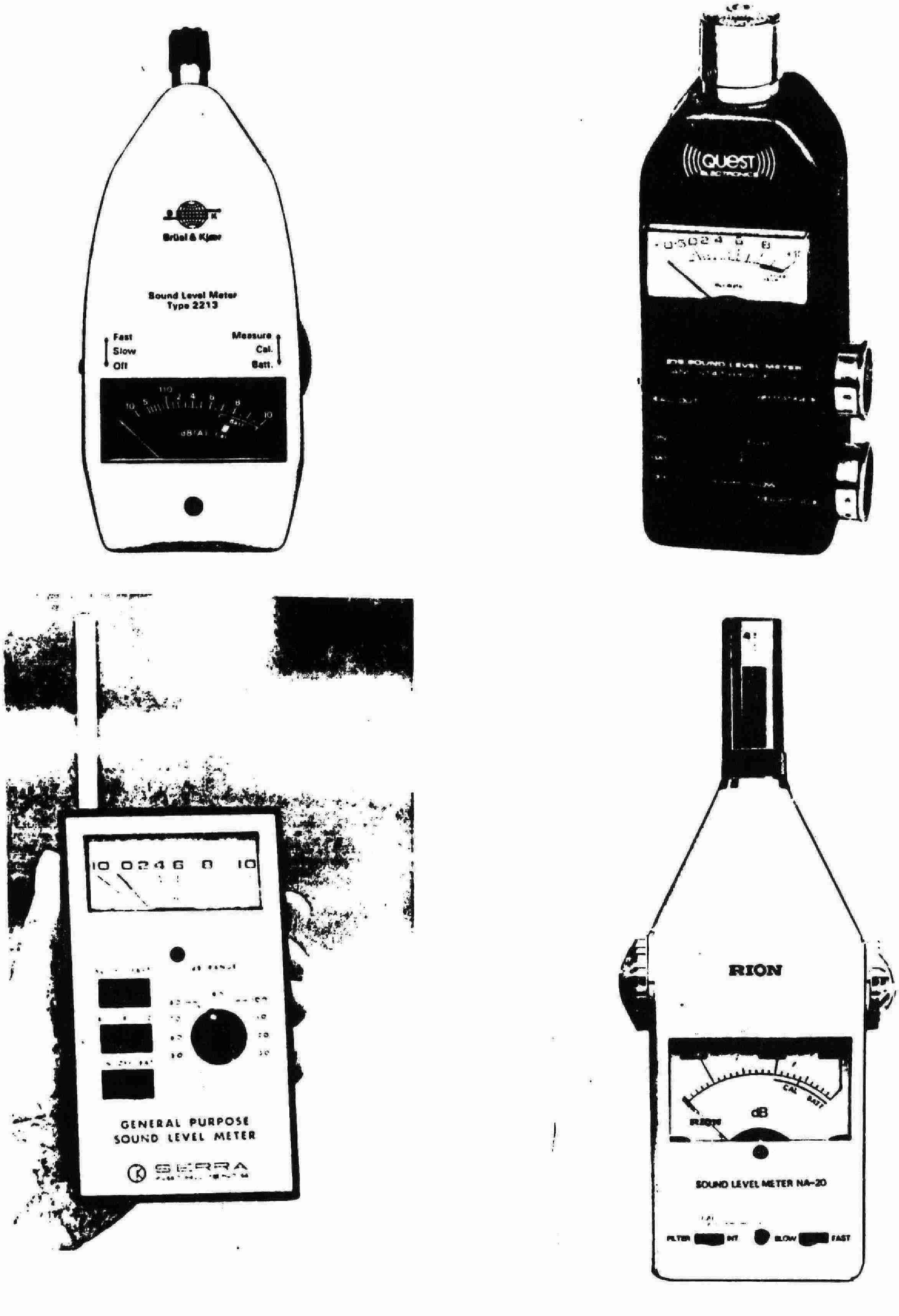


Figure 3.1 Examples of general purpose sound level meters

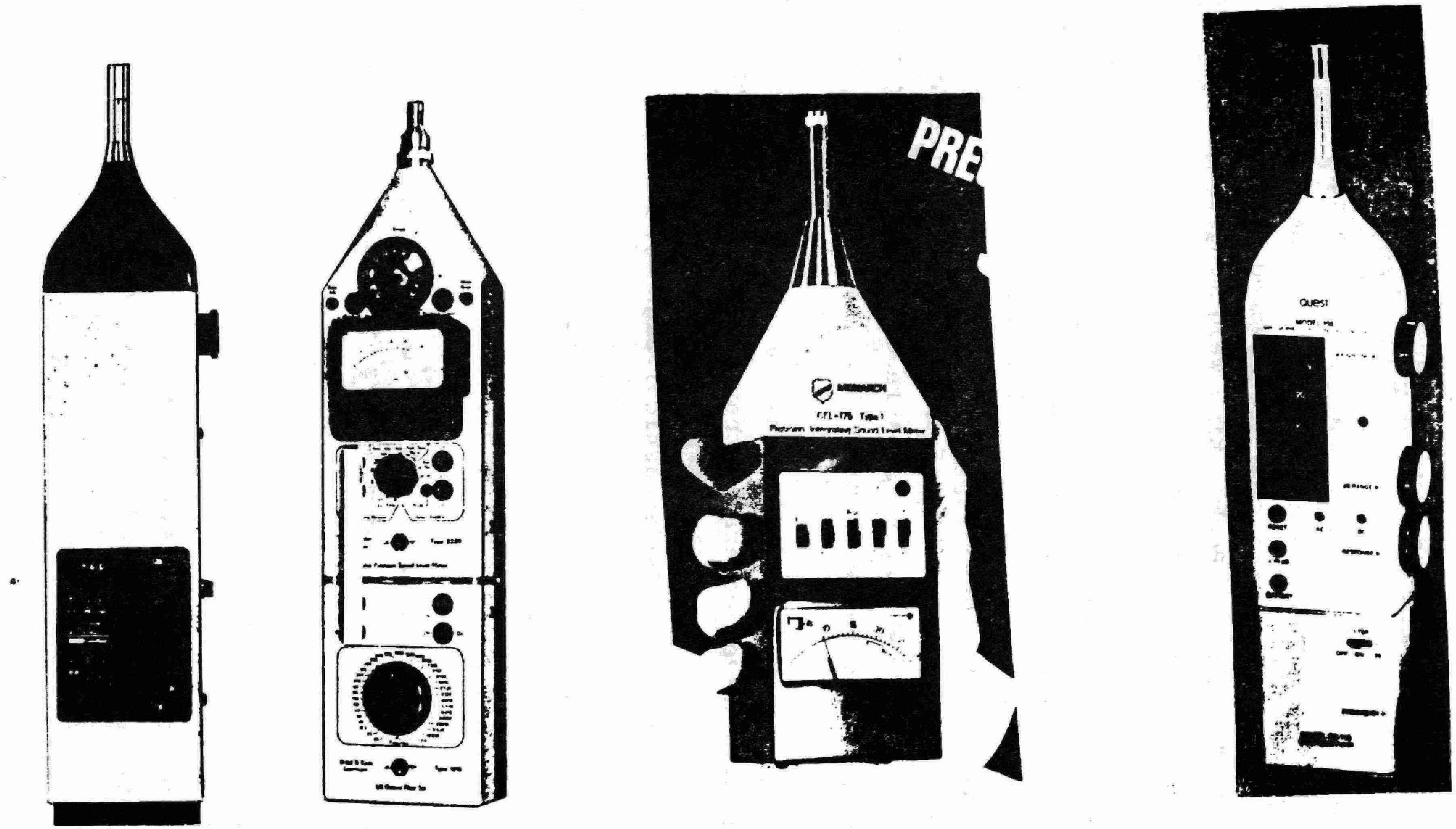


Figure 3.2 Examples of precision sound level meters

2.3 Integrating Sound Level Meters for Leq Measurements

As described earlier in this Chapter, the conventional sound level meters average (integrate) the acoustic signal. The averaging time is selected by the "Slow", "Fast", "Impulse", "Peak", time-weighting characteristics incorporated in the meter.

The integrating sound level meter simply carries the averaging idea a step further by providing a much wider choice of averaging times. Instead of being limited to a maximum averaging time constant of one second (using "Slow" time-weighting characteristic of the meter), an integrating sound level meter may be capable of averaging over many minutes, hours and even days.

Another difference between the conventional and integrating sound level meters is that the latter gives the same weight to all the earliest and latest (and all - in between) parts of the acoustical signal, while a conventional sound level meter gives greater weight to the more recently occurring part of the sound signal then to the older parts (exponential). It is important to remember the following rules:

- If a sound is constant in level, conventional and integrating sound level meters will give identical results.

- If a sound signal fluctuates in level, the conventional sound level meter reading will fluctuate while the integrating sound level meter will average the fluctuations and produce an averaged reading.

Although a conventional sound level meter can be used to measure long-time average level, the operator must sample and record many sound level readings while making certain that in this sampling process, a significant noise event is not missed. Then, he must carry out manually the calculations of the average. The integrating sound level meter performs the measurement (integrating samples of sound signal) automatically, improving accuracy and reducing the possibility of measurement error.

Commercially available integrating sound level meters can be classified as being general application or special application. The general application instruments have a full range of operating facilities and are usually capable of measuring Leq, maximum sound level and integration time (or elapsed time). Typical examples of such instruments are shown in Figure 3.3.

The integration time can be preset for automatic operation or controlled manually, and a pause control is provided to permit inhibition of unwanted noise events and allow integration to be taken at various locations. Full facility instruments are capable of making ordinary sound level measurements using various frequency filters and detector characteristics (i.e. "Slow", "Fast", "Impulse", "Peak"). They may also be able to operate with plotters, printers and other output devices.

The special application integrating sound level meters are usually smaller, lower cost instruments intended for special industrial and community noise measurements. They include many of the features of the general application unit but do not provide the full range of frequency weighting, detector characteristics and integration time presets. Typical examples of special application integrating sound level meters are shown in Figure 3.4.

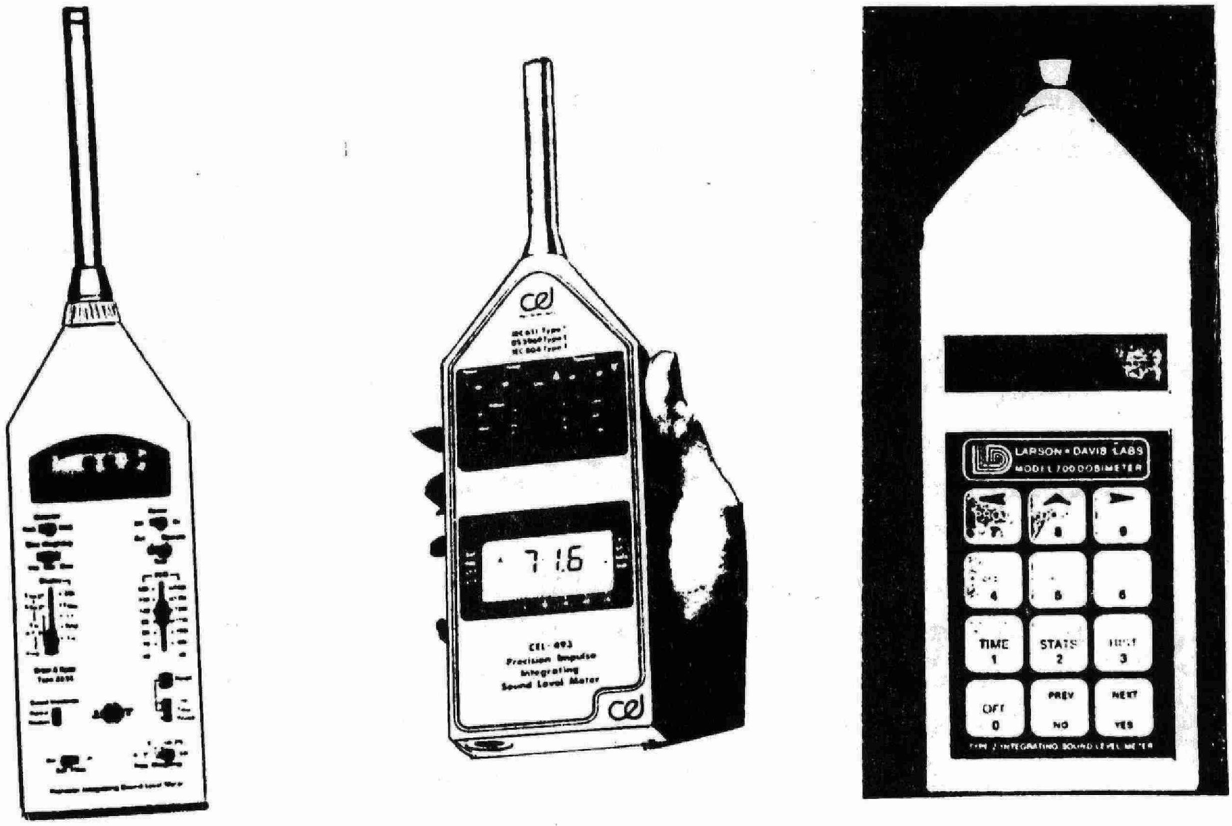


Figure 3.3. General application integrating sound level meters

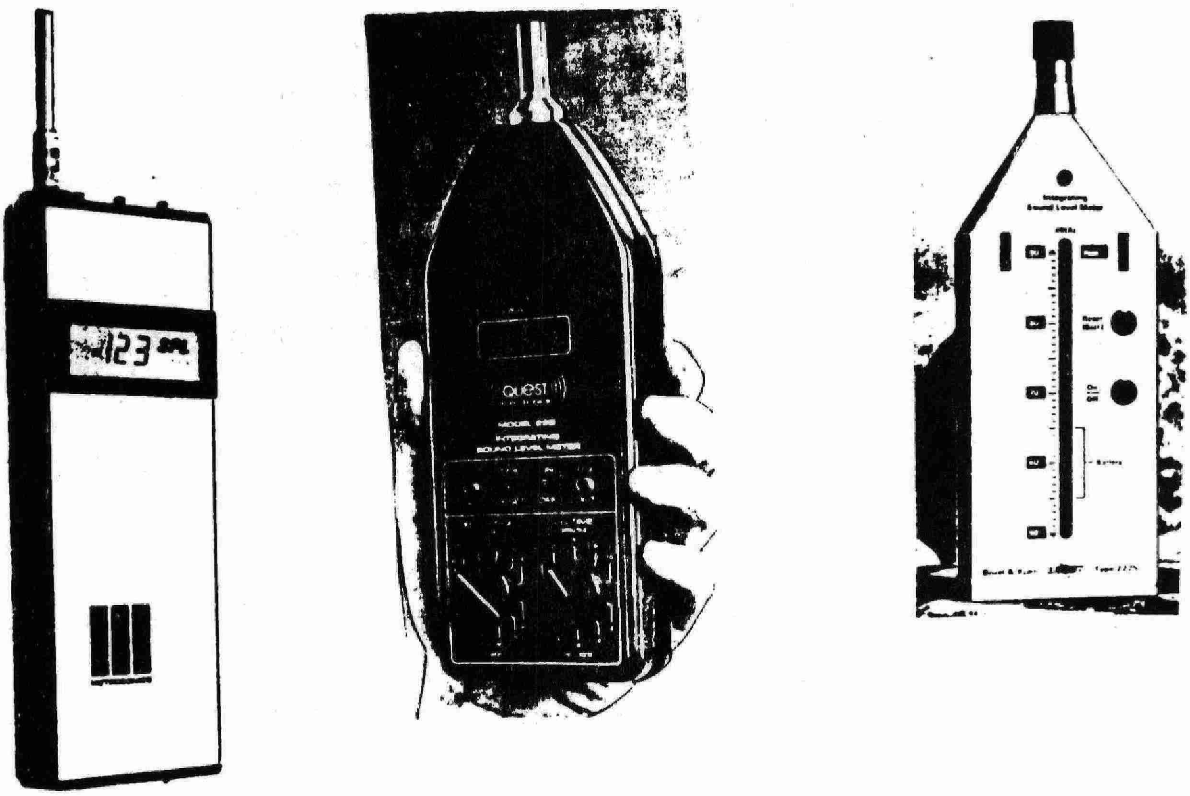


Figure 3.4. Special application integrating sound level meters

2.4 Acoustic Calibrators

In order to obtain reliable results of noise measurements, calibration checks of the sound level is required. This ensures the reproductibility of the measurement and, if properly carried out, gives correct absolute values. A sound level meter can be accurately calibrated by applying a reference source, which produces a known sound level at specified frequency, to the sound level meter's microphone and adjusting the sensitivity (on the sound level meter) until the sound pressure level indicated by the meter agrees with the sound pressure level of the reference source (calibrator). This calibration should be performed immediately before and after measurement on location.

Most calibrators use an electrical signal to drive a diaphragm which serves as a loudspeaker in the calibration cavity. Because the calibration level is a function of the applied voltage, a regulating circuit is used to maintain this applied voltage at a constant level. Most calibrators of this type operate at 1 kHz. At this frequency, the weighting filters have no gain, offering the advantage that a 1 kHz calibrator can be used with the sound level meter in the A-weighting mode without using any correction factors. An example of a typical electrically controlled acoustic calibrator and a sound level meter fitted with the calibrator are shown on Figure 3.5.

3.0 MEASUREMENT TECHNIQUES

When performing acoustical measurements, due consideration must be given to the use of the sound level meter and to

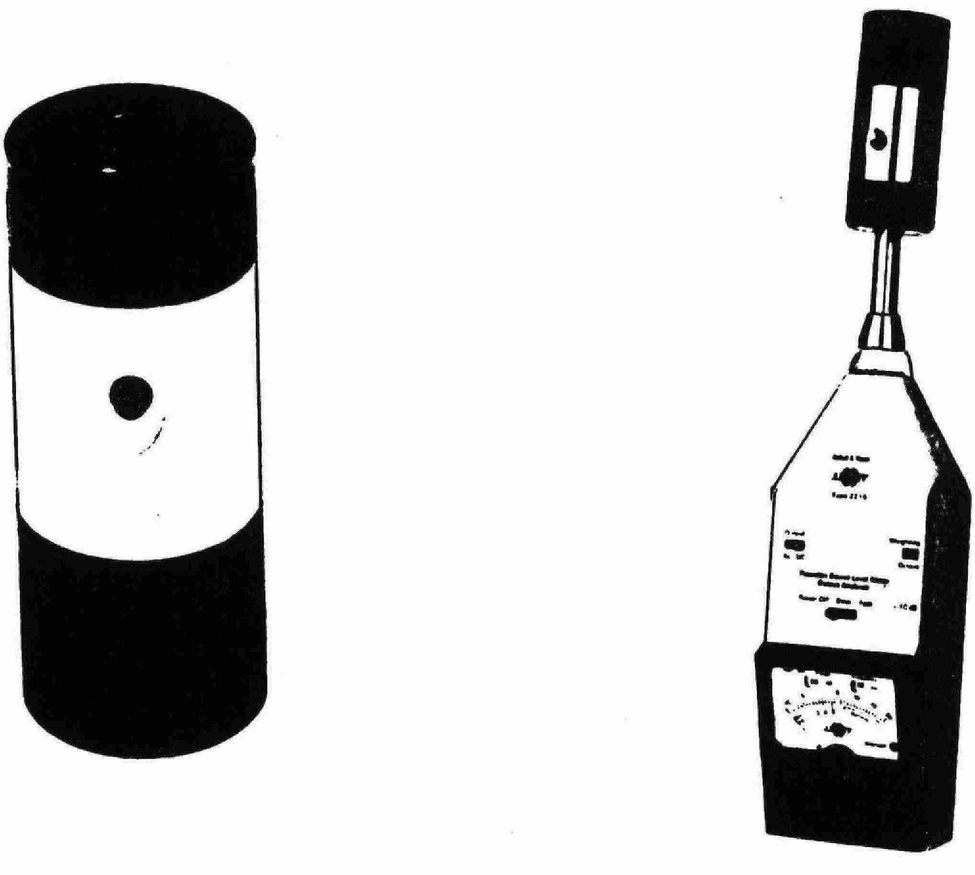


Figure 3.5. Acoustic calibrator and sound level meter fitted with the calibrator

the relationship between the instrument and the noise source. Improper use of the meter will affect the accuracy of acoustical measurements.

The key to operating a sound level meter is to use it in a manner that will not alter the sound field being measured. Also, the effect of background noise and meteorological conditions should be taken into account to ensure reliable measurement results.

The following is a more detailed discussion of these effects:

3.1 <u>The Effect of Reflecting Surfaces</u>

When measuring outdoor noise sources, the presence of walls, obstructions and even the operator, can affect the sound field of the source. This disturbance can cause incorrect measurements. The errors are most marked in the frequency range of 200-4000 Hz, when the physical dimensions of objects are similar to, or larger than, the wavelength of the sound.

The most effective way to avoid these errors is to select measurement sites which are far-removed from any reflecting surfaces. The meter should be held (or positioned on the tripod) away from the operator's body to prevent sound reflections. Also the operator must not be located between the meter and the noise source. In order to reduce errors due to the presence of the operator, the sound level meter may be attached to the pistol clip and held at arm's length during the measurements.

3.2 The Effect of Microphone Orientation

There are two types of microphones used in sound measurements. The first type of microphone should be pointed towards the sound source if the sound field is estimated to be coming from one direction. This is known as a free field response type.

Some microphones are designed to be pointed at right angles to the source (grazing incidence). These microphones are known as random-incidence response types.

3.3 The Effect of Background Noise

Background noise can cause errors in acoustical measurements whenever it is within 10 dB of the noise being measured. If increase in the sound pressure level generated by noise source under measurement, compared to the background sound pressure level alone, is 10 dB or more, the background noise has virtually no effect, and the result of measurement is essentially the sound pressure level generated by the noise source. However, for example, if the sound pressure level measured in the vicinity of a ventilating fan is 66 dBA, and the background level at the same location, measured with the fan shut off, is 57 dBA or higher, the result of fan noise measurement will not be reliable without special adjustments. In such a situation, it is best to reschedule the measurements until the background level on the site drops to below 55 dBA.

3.4 The Effect of Meterological Conditions

Outdoor noise measurements should not be performed in the presence of excessive wind, humidity, and outside the

temperature range specified by the manufacturer of the measuring instrumentation.

The following limitations on meterological parameters during noise measurements generally apply:

(a) wind speed in excess of 15 km/h;
(b) temperature, outside the range -10°C to 50°C;
(c) relative humidity in excess of 90%.

High wind speeds generate turbulence around the microphone. The turbulence causes pressure fluctuations which the microphone senses as sound. This "pseudo-sound" is often of sufficiently high level to mask the actual noise under investigation.

Also, sound measurements should not be attempted under conditions of temperature beyond the meter specifications. The temperature range of operation of the meter is usually quoted in the instruction manual.

High humidity conditions can cause measurement errors. Most meters are not to be used if the humidity exceeds 90%. If condenser microphones are being used, moisture can condense between the diaphragm and back plate making measurements unreliable.

In addition to the above limitations, it is a good practice to note the wind direction as the propagation of sound in air can be strongly affected by wind, especially close to the ground surface.

CHAPTER 4

ENVIRONMENTAL NOISE CRITERIA

1.0 INTRODUCTION

Criteria for the emission of sounds from various sources are required for two basic reasons. First, to determine if the sound generated by a particular source is excessive, and secondly to provide an objective sound level for use in the design of noise control measures.

This chapter outlines the basic philosophy used by the Ministry when establishing criteria for the common sources of environmental noise which could be effectively dealt with at the municipal level.

2.0 MUNICIPAL CONTROL OF ENVIRONMENTAL NOISE

Environmental noise may be defined as any unwanted sound which is heard outdoors in a community or in the natural environment.

Noise due to road and rail traffic, aircraft and industry are common examples of large scale pollutants of our sound environment.

As a result of the seriousness of the noise problem in our society, all three levels of government have a direct interest in the abatement of environmental noise. The extent of their responsibilities with regard to a particular noise problem is dependent on the type of source involved.

Since certain types of noise sources, for example industry, commercial establishments and construction equipment, can best be controlled at the municipal level, powers to regulate the sounds from these types of noise sources were granted to municipalities through an amendment to the Environmental Protection Act. The amendment was passed by the Legislature and came into force on October 8, 1975.

2.1 Need for Noise Standards

To assist municipalities in adopting noise by-laws suitable for their particular needs, the Ministry has adopted standards for certain common types of environmental noise which could be effectively dealt with at the municipal level.

These standards are required to define levels of environmental noise which will protect the public's health and welfare with an adequate margin of safety. Both qualitative (subjective) and quantitative noise standards have been incorporated into the Ministry's Model Municipal Noise Control By-Law for use by the municipalities. These standards will be discussed in detail in Section 3.

2.2 Adoption of Quantitative Standards

The following outlines the major considerations made by the Ministry when adopting quantitative standards for use in the Model By-Law.

- Choice of Sound Level Descriptors

The choice of descriptors for rating particular sounds is an area of continuing discussion in the acoustical community.

Many descriptors exist [4] and at present no agreement has been reached as to the best descriptor(s) for all types of sounds. Sociological surveys, jury testing and other research methods have, however, provided valuable information on the relative merits of the various descriptors making possible the selection of only a few to cover most situations.

The following are the descriptors commonly used in the Model By-Law:

(a) the energy equivalent sound level, Leq measured in dBA, the best single indicator of annoyance due to most types of environmental noise;

(b) the ninetieth percentile sound level, L_{90}, used as the basic descriptor for evaluating sounds in rural areas; and

(c) the impulse sound level (measured in dBAI) which, in addition to annoyance, accounts for the reactions of startle and fear brought on by certain types of impulsive sounds.

o Adoption of Sound Level Limits

Prior to adopting sound level limits for various types of environmental noise, the Ministry conducted extensive surveys of the most recent studies on the development of noise standards and consulted with industries and various public/private agencies.

The major factors considered by the Ministry when adopting sound level limits for various types of environmental noise included:

(a) the nature of the source;

(b) the characteristics of the sounds generated by the source;

(c) the acoustic environment at the point of reception;

(d) the availability and practicality of the technology required for the measurement and control of these sounds.

The sound level limits for various types of noise commonly heard in a community are contained in a series of technical publications (NPC Publications) which are included in the Model By-Law.

3.0 MINISTRY STANDARDS

The following describes the types of standards contained in the Model By-Law. Some of the common noise sources for which standards have been adopted by the Ministry and incorporated into the Model By-Law are also listed.

3.1 Qualitative (Subjective) Standards

Qualitative (subjective) standards have been incorporated into the Model By-Law to provide municipalities with a simple means of dealing with noise problems which could be handled in a relatively straightforward manner. These standards are often suitable for use in situations where the noise problems are not severe. Further, these standards provide the only practical means of controlling certain common types of community noise, such as the sounds due to dogs barking, people shouting, and so forth.

The qualitative (subjective) standards prohibit the emission of certain types of sounds at an intensity which would cause these sounds to be clearly "audible" at a point of reception within a quiet zone or residential area of a community during a specified time period(s).

3.2 Quantitative Standards

A more comprehensive approach to environmental noise control is required in situations where the noise problems are complex. In such cases quantitative standards are used to determine if the sounds emitted by a particular source are excessive. These standards, it should be noted, are based on a compromise between two opposing influences, namely, minimizing annoyance due to noise and minimizing the cost of noise control measures required to achieve this goal.

The Model By-Law contains two types of quantitative standards: (a) sound level limits at the point of reception which are applied to stationary sources, and (b) sound emission standards which are used for non-stationary sources.

3.2.1 Sound Level Limits At the Point of Reception

The basic standard used to evaluate sound from a stationary source is the background sound level. This background sound level is used to determine if the sound generated by the source is excessive. The evaluation is made at the point of reception. The point of reception is defined as any point within a quiet zone or residential area at which sound from the source is received.

Where the sound generated by the source is highly intrusive, a specific sound level limit is also applied.

In situations where both standards apply the least restrictive is used. It should be noted that in the Model By-Law sounds from a stationary source which produce an equivalent sound level, Leq, of 40 dBA or less at the point of reception are exempt from further consideration.

o <u>Background Sound Levels</u>

Certain types of sounds generated by stationary sources are annoying simply because they can be heard above the background sounds. The following criteria are used to determine the acceptability of sounds generated by such sources.

<u>Urban Areas</u>:

In urban areas noise due to road traffic provides a good standard for the evaluation of sounds from most stationary sources, since it is a characteristic of the sound environment, fairly predictable and relatively constant from day to day.

The descriptor used in the noise standard is the equivalent sound level, Leq, the best <u>single</u> indicator of annoyance due to noise generated by road traffic. Hourly equivalent sound levels due to road traffic are used by the standard to account for variations in traffic noise with time.

The sound levels from most stationary sources are considered to be acceptable if, at the point of reception in a quiet zone or a residential area within an urban community, the one hour equivalent sound level due to the source does not exceed, in any one hour, the corresponding one hour equivalent sound level due to road traffic.

Rural Areas:

Where the sound environment at a point of reception is normally dominated by natural sounds, the standard used to determine if the sounds from most stationary sources are excessive is the ninetieth percentile sound level, L_{90}, of the background sounds. Note: The L_{90} sound level is the sound level exceeded 90% of the time and is commonly referred to as the background sound level.

In rural areas the noise due to most stationary sources is considered to be excessive if at a point of reception during any one hour period, either the Leq or L_{90} sound level due to the source is greater than the allowable excess above the corresponding one hour L_{90} sound level of the background sounds.

o Specific Sound Level Limits

Some sounds due to their highly intrusive nature are annoying regardless of the sound environment at the point of reception. Background sound levels and specific sound level limits are the standards which are employed to determine the acceptability of these types of sounds. The standard which is least restrictive is applied.

The following lists some of the common stationary sources for which specific sound level limits have been adopted by the Ministry and incorporated into the Model By-Law.

(a) Industrial Metal Working Operations

Specific sound level limits are used for industrial metal working operations which generate impulsive sounds that

are frequent (e.g. forging, punching, cutting, etc.) but are not considered to be quasi-steady impulsive. The sound level limits take into account the year the noise source began operating. These limits are contained in Publication NPC-105 of the Model By-Law.

(b) Sources of Impulsive Sound (Single Event)

A fixed sound level limit (100 dBAI) is used to regulate infrequent impulsive sounds which occur as single seemingly independent events.

(c) Blasting Operations

Fixed limits for sound (concussion) and vibration levels have been adopted to regulate noise and vibration generated by blasting operations in a mine or quarry.

The limits take into account the annoyance to local residents and the potential for structural damage. These limits are contained in Publication NPC-119 of the Model By-Law.

(d) Residential Air Conditioners

Specific sound level limits are used for residential air conditioning devices (i.e. central air conditioners and wall/window units).

These limits take into account the year the particular unit was installed (see Publication NPC-116).

3.2.2 Sound Emission Standards

Due to the mobile nature of a non-stationary source, a noise standard for this type of source must be

independent of the sound environment at the point of reception and it must be applied at some fixed distance relative to the source. This standard is referred to as the sound emission standard.

The Model By-Law contains sound emission standards for the following sources. These standards are applied when the noise from these sources impact quiet zones and residential areas.

(a) Motorized Conveyances

Publication NPC-118 contains sound emission standards for heavy vehicles with governed diesel engines. By heavy vehicle is meant any motorized conveyance having a registered gross vehicle weight of more than 4,500 kg.

These standards, which take into account the year of manufacture of the vehicle, provide a means of reducing unnecessary noise on Ontario's roads caused by heavy vehicles in need of repair.

(b) Construction Equipment

Standards contained in Publication NPC-115 can be used to regulate sound emissions from the following categories of new construction equipment:

(i) excavation equipment (including dozers, loaders, and backhoes);

(ii) pneumatic pavement breakers;

(iii) portable air compressors; and

(iv) tracked drills.

Note: The standards for a particular category of construction equipment apply to all types of equipment within that category provided the items of equipment: (i) are used for similar applications, and (ii) have been manufactured in the same year as the items listed in the Publication.

(c) Powered Lawn Mowers

Sound emission standards for walk-behind powered lawn mowers are contained in Publication NPC-117. These standards can be used for lawn mowers powered by electric motors or internal combustion engines. The standards take into account the year the appliance was manufactured.

4.0 REQUIREMENTS FOR SOUND LEVEL ADJUSTMENTS

To determine if sound from a source is excessive, the measured sound level is compared to the applicable noise standard.

Prior to performing this comparison adjustments (in decibels) must be made to the measured sound levels of certain types of sounds. These adjustments are required to ensure that the sound levels reflect the annoyance caused by these sounds.

The following describes the types of sounds for which adjustments are prescribed in Publication NPC-104 of the Model By-Law.

4.1 Intermittent Sounds

A sound is referred to as being intermittent if it is not continuous but lasts for more than one second.

An adjustment is subtracted from the measured sound level to account for the fraction of an hour the source was not operating; one hour being the basic time period used in the Model By-Law. Adjustments from 0 dB to about 20 dB will be required depending on the amount of time the source was not operating.

4.2 Sounds Exhibiting Special Characteristics

Due to their characteristics, certain sounds appear louder than other sounds having the same sound level. In order to account for the apparent loudness of these sounds, positive adjustments are made to the measured sound levels.

The following are the types of sounds for which adjustments are made. Only one adjustment may be made to the sound level generated by a particular source.

(a) Tonal Sounds

A tonal sound is any sound which can be distinctly identified through the sensation of pitch. Circular saws, transformers and sirens are examples of sources which generate tonal sounds.

If a sound has a pronounced audible tonal quality such as a whine, screech, buzz or hum, the measured sound level is increased by 5 dB.

(b) Varying Sounds

If a sound has an audible cyclic variation such as a beat or other modulation in amplitude, the measured sound level is increased by 5 dB. An example of a beating sound is the sound generated by two engines operating at about the same RPM.

(c) Quasi-Steady Impulsive Sounds

An impulsive sound is a single pressure pulse or a single burst of pressure pulses which has a duration of less than one second. A quasi-steady impulsive sound is a sequence of impulsive sounds which are repeated within a time interval of less than 0.5 seconds. Pavement breakers and rivetting guns are examples of sources which generate quasi-steady impulsive sounds.

If a sound is quasi-steady impulsive, the measured sound level is increased by 10 dB.

CHAPTER 5

ROAD TRAFFIC NOISE PREDICTION

1.0 INTRODUCTION

In the field of acoustics, prediction methods are used primarily to determine the noise impact from various transportation noise sources such as roads, railways and aircraft operations.

There is a number of reasons for the extensive use of prediction methods in noise impact assessment. First, it allows persons who do not have measurement capabilities to obtain an indication of the noise levels on a particular site. Second, it allows the noise levels on a site to be determined when the constraints of time, money, distance, weather and instrumentation do not permit on-site measurements. The use of prediction methods also allow the evaluation of changes in the transportation facility noise source. For example, the effect of a future increase in the volume of traffic on a particular road can easily be calculated. The prediction methods also allow the effectiveness of some noise control measures to be evaluated particularly the effect of increasing the distance between the noise source and the receiver.

This section will describe the prediction method used extensively by this Ministry to determine the noise impact from road traffic.

2.0 GUIDELINES FOR ROAD TRAFFIC NOISE ASSESSMENT

In July 1986 the Ministry of the Environment published a guideline manual for the prediction of road traffic noise. The manual presents a procedure required by this Ministry for the prediction of energy equivalent sound levels, Leq, due to road traffic and the procedure supercedes all other previously used prediction methods. A copy of the publication is enclosed as Appendix A.

2.1 Basic Elements of the Prediction Model

The energy equivalent sound level produced by each class of vehicle is given by:

$Leq(h)_i = [L_o]_{E_i}$ reference energy mean emission level

$+ 10 \log [(N_i \pi D_o)/(S_i T)]$ traffic flow adjustment

$+ 10 \log [D_o/D]^{1+\alpha}$ distance adjustment

$+ 10 \log [\psi_\alpha(\emptyset_1, \emptyset_2)/\pi]$ finite roadway adjustment

$+ \Delta s$ shielding adjustment (5.1)

where $Leq(h)_i$ is the hourly equivalent sound level of the ith class of vehicles.

$[L_o]_{E_i}$ is the reference energy emission level of the 8th class of vehicles.

N_i is the number of vehicles in the ith class passing a specified point during some specified time period.

D is the perpendicular distance, in metres, from the centerline of the traffic lane to the observer.

D_o is the reference distance at which the emission levels are measured. In the model D_o is 15 m, D_o is a special case of D.

S_i is the average speed of the ith class of vehicles and is measured in kilometres per hour (km/h).

T is the time period over which the equivalent sound level is computed.

α is a site parameter whose values depend upon site conditions.

ψ_α is a symbol representing a function used for segment adjustments, i.e. an adjustment for finite length roadways.

Δ_s is the attenuation, in dB, provided by some type of shielding such as barriers, rows of houses, densely wooded areas, etc.

2.1.1 Reference Hourly Sound Level

The reference hourly sound level for all three classes of vehicles is defined as:

$$Leq_R(h) = 10 \log [\Sigma(\text{antilog } [(L_o)_{E_i}/10]) * P_i] + 10 \log [ND_o/S] - 25 \qquad (5.2)$$

where P_i = Percentage of ith class of vehicle (expressed as a fraction of the total volume)

S = posted speed limit in km/h

i = 1, 2 and 3

The reference energy mean emission levels measured at the reference distance of 15 m for automobiles, medium trucks and heavy trucks are given below and also plotted in Figure 5.1:

$$(L_o)_{E_A} = 38.1 \log (S) - 2.4$$

$$(L_o)_{E_{MT}} = 33.9 \log (S) + 16.4$$

$$(L_o)_{E_{HT}} = 24.6 \log (S) + 38.5 \qquad (5.3)$$

For a specific reference distance of 15 m and a reference traffic volume of 40 vehicles per hour, the reference hourly sound level can be expressed as:

$$Leq_R(h) = 10 \log [\Sigma(\text{antilog } [(L_o)_{Ei}/10]) * P_i] - 10 \log S + 2.78 \qquad (5.4)$$

$$i = 1,\ 2 \text{ and } 3$$

The above expression defines the reference hourly sound level presented in Appendix A, Tables 3 to 6.

For heavy trucks travelling in the upgrade direction, the adjustment shall be made by multiplying the percentage of heavy trucks by an adjustment factor given in Table 1 of Appendix A, before applying the above formula or using Tables 3 to 6.

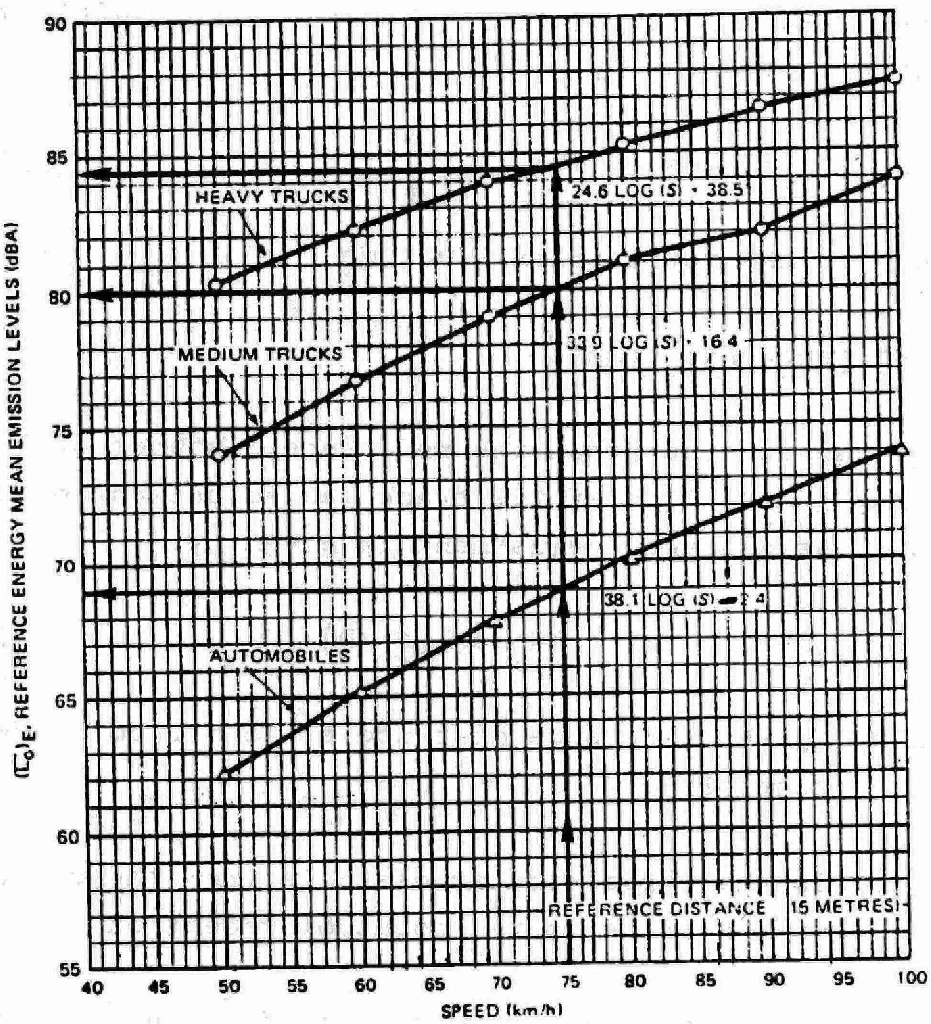


Figure 5.1. Reference energy mean emission levels as a function of speed

2.1.2 Adjustments to Reference Level

(a) Traffic Volume

For volumes other than the reference volume of 40 vehicles per hour, an adjustment must be added. The traffic volume adjustment is given by:

$$\Delta_{vol} = 10 \log (V/40) \qquad (5.5)$$

where V is the total traffic volume

(b) Distance Adjustment

For distances other than the reference distance of 15 m from the centre line of the track, an adjustment must be added. The distance adjustment is given by:

$$\Delta_{dist} = (1 + \alpha) * 10 \log [D_o/D] \qquad (5.6)$$

where D_o is the reference distance of 15 m from track centreline,

D is the perpendicular distance from the centreline of the track to the point of reception,

and α is the ground absorption co-efficient defined by:

$$\alpha = 0.5 \qquad h \le 3m$$
$$= 0.715\ (1-h/10) \qquad 3m < h < 10m$$
$$= 0 \qquad h \ge 10m$$

where h is the total effective height. For reflective surface, α is equal to 0. The total effective height is computed by adding together the height

of the point of reception above the ground, the effective shielding height between the source and the receptor, and the effective source height of the road traffic.

The effective source height in metres is given by:

$$S = p^{0.25} \tag{5.7}$$

where p is the unadjusted percentage of heavy trucks.

It should be noted that a lower limit of 0.5 m and an upper limit of 2.4 m apply to the source height.

(c) Road Element Size

When the ground is non-reflective or when the calculation considers a finite section of the track, an adjustment must be added. The value of the adjustment is given by:

$$\Delta_{\text{road size}} = 10 \log \left[(1/\pi) \int_{\emptyset_1}^{\emptyset_2} (\cos \phi)^{\frac{1}{2}} \, d\phi\right] \text{ for non-reflective surfaces}$$

$$= 10 \log \left[[\emptyset_2 - \emptyset_1]/\pi\right] \text{ for reflective surfaces} \tag{5.8}$$

where $\emptyset_1$ and $\emptyset_2$ are the angles subtended by the track section at the point of reception, see Table 10 of Appendix A.

(d) Pavement Surface

An adjustment Δ_{ps} must be added to account for pavement surface type. This adjustment is described in Section 2.2 (g)(iv) of Appendix A.

(e) Adjustment for Shielding by Dense Woods and Rows of Houses

An adjustment must be added to account for shielding of dense woods or rows of houses. This adjustment is described in Section 2.2(g)(v) of Appendix A.

(f) Barrier Adjustment

The barrier adjustment accounts for barrier attenuation.

The barrier adjustment is discussed in detail in Chapter 9 and in Appendix A.

2.2 Road Traffic Variables

The following variables are included in the prediction model:

(a) Volumes of cars, medium trucks and heavy trucks/hour
(b) Traffic flow speed
(c) Road gradient
(d) Distance from the centreline of road to the receiver
(e) Total effective height
(f) Road element size
(g) Pavement surface type
(h) Shielding

2.3 Worked Example

Given - automobiles	910 vph
- medium trucks	20 vph
- heavy trucks	70 vph
- posted speed	80 km/h
- distance from centreline	30 m

- road gradient 0%
- road surface type normal
- topography flat

2.3.1 Mean Emission Levels at 15 m

Automobile $[L_o]_{E_A}$ = 38.1 log (S) - 2.4
= 38.1 log (80) - 2.4
= 72.51 - 2.4
= 70.11 dBA

Medium trucks $[L_o]_{E_{MT}}$ = 33.9 log (S) + 16.4
= 33.9 log (80) + 16.4
= 64.51 + 16.4
= 80.91 dBA

Heavy trucks $[L_o]_{E_{HT}}$ = 24.6 log (80) + 38.5
= 46.8 + 38.5
= 85.32 dBA

2.3.2 Reference Hourly Sound Level at 15 m

Using equation (5.2)

$$\begin{aligned} Leq_R(h) &= 10 \log [10^{7.011} * 0.91 + 10^{8.091} * 0.02 \\ &\quad + 10^{8.532} * 0.07] + 10 \log [1000 * 15/80] - 25 \\ &= 75.52 + 22.73 - 25 \\ &= 73.25 \text{ dBA} \end{aligned}$$

2.3.3 Distance Adjustment

$$\begin{aligned} \text{Source height, } S &= (p)^{0.25} \\ &= (7)^{0.25} \\ &= 1.63 \text{ m} \end{aligned}$$

$$\text{Total effective height, } h = s + t + p + r$$
$$= 1.63 + 0 + 0 + 1.5$$
$$= 3.13 \text{ m}$$

$$\alpha = 0.715\ (1 - h/10)$$
$$= 0.715\ (1 - 3.13/10)$$
$$= 0.49$$

$$\Delta_{dist} = 10 \log (D_o/D)^{1+\alpha}$$
$$= 10 \log (15/30)^{1+0.49}$$
$$= -4.5 \text{ dB}$$

2.3.4 Road Element Size

$$\Delta_{road\ size} = 10 \log [[1/\pi] \int_{\emptyset_1}^{\emptyset_2} (\cos \phi)^{\frac{1}{2}}\, d\phi]$$
$$= 10 \log [[1/\pi] \int_{-90}^{90} (\cos \phi)^{\frac{1}{2}}\, d\phi]$$

The indicated integration has been performed numerically using the Simpson's Rule:

$$\Delta_{road\ size} = -1.2 \text{ dB}$$

2.3.5 Road Leq(h)

$$Leq(h) = Leq_R(h) + \Delta_{dist} + \Delta_{road\ size}$$
$$= 73.25 + (-4.5) + (-1.2)$$
$$= 67.55$$
$$= 68 \text{ dBA}$$

Therefore, the Leq due to road at a distance of 30 m is 68 dBA.

2.4 Effect of Changing the Traffic Flow Conditions on the Predicted Noise Levels

2.4.1 Effect of Increasing the Traffic Volume

Table 2 of Appendix A or the term 10 log (V/40) indicate the relationship between traffic volume and sound level.

A doubling of the traffic volume (and keeping the other variables constant) results in a 3 dB increase in the sound level.

2.4.2 Effect of Changing the Traffic Flow Speed

Changing the traffic flow speed have a slightly different effect on the sound levels for each classification of vehicles and is dependent on the overall composition of the three classes of vehicles.

In general, the increase in sound levels is about 1-2 dB for every 10 km/h increase in speed and the maximum increase is 3 dB.

2.4.3 Effect of Increasing the Distance

The term in the model which deals with distance attenuation is 10 log $(D_o/D)^{1+\alpha}$.

Reflective Surface

For ground absorption co-efficient, α, equal to zero, the pattenuation rate is 3 dB per doubling of distance.

Non-Reflective Surface

For ground absorption co-efficient, α, equal to 0.5 (total effective height ≤ 3 m), the attenuation rate is 4.5 dB per doubling of distance.

For total effective height greater than 3 m and less than or equal to 10 m, α is given by 0.715 (1-h/10). The attenuation rate varies between 4.5 to 3 dB per doubling of distance. And for total effective height greater than 10 m, α is zero. The attenuation rate is 3 dB per doubling of distance.

2.5 Effect of Reflections

The effect of reflections from building facades on the resultant sound level predicted at outdoor living areas is discussed in Section 4.1 of Appendix B.

CHAPTER 6

NOISE CONTROL BY-LAW OVERVIEW, STATIONARY SOURCES, INDUSTRIAL NOISE AND BLASTING

1.0 BACKGROUND

The law concerning noise goes back very many years. Noise was treated originally as an inconvenience or a nuisance or as an interference with the use of property. At some stage in the past, municipal authorities got involved in assisting complainants and restraining the activities of noise makers by developing and enforcing municipal by-laws to regulate or prohibit noise.

In Ontario, this resulted in a provision in the Municipal Act permitting the Council of a municipality to pass a by-law prohibiting the ringing of bells, the blowing of horns, shouting and unusual noises or noise likely to disturb the inhabitants. The noise in this Municipal Act By-Law was referred to as disturbance or inconvenience, and as nuisance or an interference with the property rights.

It is only in the very recent past that noise has been thought of as an environmental contaminant; in other words, as pollution. In 1971, when sound and vibration were defined as contaminants under the Environmental Protection Act, the Ministry of the Environment initiated studies of environmental noise, the sources and characteristics of noise which gave rise to complaints, methods of abating noise, variation of noise levels in various community settings and associated technical aspects of noise measurements and assessment procedures.

It was generally recognized that the federal, provincial and municipal governments would each have roles to play in effective noise control programs.

The authority under the Ontario Municipal Act for controlling noise was found to be too narrow to permit adequate scope. Accordingly, an additional tool was given to municipalities by the enactment in 1974 of an amendment to the Environmental Protection Act, empowering local municipalities, subject to the approval of the Minister of the Environment, to pass by-laws regulating the emission of sound and vibration and clearly authorizing modern techniques for noise measurement and control. The municipalities were to be provided with a Model Noise Control By-Law and with adequate permissive legislative authority under the Environmental Protection Act to adopt such by-law.

The Model Municipal Noise Control By-Law, developed by the Ministry staff, has two formats. Part I is a simple Qualitative (Subjective) By-Law likely to be suitable for smaller municipalities with less complex noise problems.

Part II is a Comprehensive By-Law with both quantitative and qualitative portions from which a municipality may select suitable sections according to its needs. This latter format is presented as a by-law proper accompanied by a number of supporting technical publications.

2.0 QUALITATIVE (SUBJECTIVE) NOISE BY-LAW, PART I

The primary difficulty with handling noise simply as a nuisance with by-laws such as may be enacted under the Municipal Act, is that the standard for determining

whether the noise should or should not be prohibited is a subjective one. Yet, the Ministry of the Environment incorporated a subjective standard in Part I of the Model Municipal Noise Control By-Law. The reason for this decision was that for certain kinds of noise there is simply no alternative. Where offensive noise is due to barking dogs, screeching of tires, noisy parties and certain other common community noises, the subjective standard is the only standard possible to apply.

In a departure from the "likely to disturb" standard established for the Municipal Act By-Laws, the subjective standard established in Part I attempts to be as objective as it possibly can be; it simply states that for a sound to be offensive it must be "clearly audible". Thus, audibility of sound from a particular source at the time noted and on the premises of a receptor as listed in provisions specified in the by-law, will constitute a violation.

The term "clearly audible" is not defined in the by-law; it would be up to the Noise Control Officer or other person testifying in court to explain what he means when he says sound was clearly audible. This term is used in the by-law to mean sound which can be heard and its information content readily perceived. That is, if one is complaining about, for example, the loud playing of radio, the resultant sound is clearly audible if it can be heard, and if the words being spoken can be easily understood or the melody of the music being played can be easily followed. The meaning of "clearly audible", with respect to sound which does not have this information content, is determined by analogy. The witness in court must be able to articulate why the sound impressed him as being clearly audible. He will have to be able to explain the information content of the sound. He may be able to say

that, as well as being clearly audible, the sound was even louder because it prevented him from having a normal conversation, or that it was even loud enough to wake him up. There may be additional ways in which a person can put into words with some objectivity how the sound impressed him.

The Subjective By-Law naturally excludes the use of any "numbers" or "quantities" in defining annoying sound. The Subjective Noise By-Law (Part I) specifies general prohibitions with reference to motor vehicles and construction equipment in Section 2, while Section 3 contains a table listing typical activities which may generate noise prohibited during specific time periods in specified zoning areas of the municipality. Flexibility is provided with regard to zoning area designation and local preference as to time when certain activities are not to be audible.

The enforcement of the Subjective Noise By-Law requires only normal hearing and judgment of a "reasonable person" on the part of the enforcing officer. The simple definition of a violation ("clearly audible") removes subjectivity from judgment of the allegedly annoying sound, provided that the person making the judgment has normal hearing ability and is a "reasonable person". This would not exclude people with exceptionally good hearing, but it would prevent the employment of a person with hearing impairment to serve as a Noise Control Officer.

The cost of implementation of the Subjective By-Law is small and neither special training nor instrumentation is required for enforcement.

3.0 COMPREHENSIVE (OBJECTIVE) NOISE BY-LAW, PART II

Municipalities experiencing complex noise problems may find that a subjective approach to local noise control is not entirely adequate. The control of noise such as that generated by machinery, construction equipment or air conditioners, warrants the use of measuring instrumentation for quantitative assessment of noise impact. Once the sound magnitude is described numerically, a standard or limit for acceptibility can be devised. Many years of research by scientists, physicians and engineers contributed to the present level of understanding and knowledge of what is "acceptable" in terms of the environmental noise impact. Naturally, various individuals may have different sensitivity, perception and subjective opinions on what annoys them, while the tolerance level in a single individual may change from time to time. Consequently, environmental noise and vibration criteria set in the Comprehensive (Objective) Noise By-Law (Part II) are based on the best current understanding of community reaction to noise, tempered by the availability and practicability of the technology for measurements and control. The range of quantitative controls covers most of every day problems and many special industrial activities such as impulsive noise, blasting, truck and construction equipment noise.

The Comprehensive Noise By-Law (Part II) includes all the provisions of the Subjective (Qualitative) By-Law (Part I), and the following additional three major sections dealing with specific sound level limits and sound emission standards:

- <u>Section 4 - General Limitations on Sound Level Due to a Stationary Source</u>

  This section refers to sound level limits applicable to noise generated by stationary sources. The basic assessment of source acceptability is made using the so called "ambient" or surrounding environmental "noise climate" at a particular location as a yard stick. The criterion is expressed as the difference between the noise from the source and the ambient noise. The ambient noise chosen for this purpose is essentially made up of the road traffic noise which pervades the locality and creates a so called "urban hum".

  It was also recognized that some noises are annoying, no matter in what kind of environment they are generated. These specific high level impulsive sources have to be restricted by an absolute limitation to reflect the increased severity of noise impact.

- <u>Section 5 - Limitation on the Sound and Vibration Levels at a Point of Reception for Specific Sources</u>

  This section refers to sound level limits applicable to noise generated by residential air conditioners and blasting operations.

  Noise generated by air conditioners has been for years a major concern in most communities, and statistically accounts for the largest number of complaints.

  In the case of blasting operations, the resultant potential impact in terms of community reaction and possible structural damage to property can be so severe, and the characteristics of the generated sound

and vibration so different from other sources, that a separate set of limits had to be established.

- <u>Section 7 - Sound Emission Standards</u>

  For certain sources, a noise limitation must be independent of the acoustic environment and must be applied at a specified reference distance relative to the source. Such a limitation is referred to as the sound emission standard and basically is applicable to non-stationary sources of sound.

  Section 7 sets out sound emission standards for domestic outdoor power tools, motorized conveyances, air conditioners and construction equipment in both residential areas and quiet zones.

Accompanying the Comprehensive Noise By-Law are various Technical Publications which reflect the state of the art in acoustics. They have been revised several times to accommodate the existing economic reality and to provide the simplest means of enforcement.

The Technical Publications provide detailed specifications for acoustic measurement instrumentation and detailed procedures for measurements of various types of sound, as well as provide general and specific numerical limits established for control of sound sources.

Some of the Technical Publications are guidelines dealing with the aspect of land use planning, noise control in rural areas, new noise source assessment information, new land use assessment information and the certification of

the Noise Control Officer. These guidelines are included to provide assistance to municipal Councils in the areas of planning, zoning, public works, building permits and, in general, municipal matters where noise considerations might be relevant.

Enforcement of a Comprehensive Noise By-Law requires acoustic instrumentation and specialized staff training. The accurate measurement of sound and vibration is a complex problem, particularly when attempting to satisfy legal requirements. In order to successfully prosecute a case based on a Quantitative Noise Control By-Law, it is essential that the instrumentation and the measurement procedures rigorously conform to the requirements set in the relevant Technical Publications. It must be conclusively demonstrated to the court that the measurements given in evidence are accurate, reliable and within the tolerances specified. Faithful observance of all of the provisions of the Technical Publications will help to convince the court of the validity of the evidence presented.

3.1 Assembly of a Municipal Noise Control By-Law and Implementation

A municipality wishing to control the noise in its jurisdiction should consider first the type of noise problems that are prevalent within the municipal boundaries, and then proceed to adopt the particular provisions of the Model Noise By-Law which address those problems best. Council may choose to adopt the Model By-Law in whole or in part so that it may best meet the particular requirements of the municipality.

Some of the quantitative controls may apply in situations where there are also applicable qualitative controls. Legally, this means that both requirements must be met. In some cases, adjustment of the by-law might be desirable. A municipality may find different parts of the Model By-Law more suitable for its purpose and may alter some of the provisions in the by-law text. However, alteration of any supporting Technical Publication is not permitted; these documents represent the culmination of extensive technical research, augmented and often guided by inputs from various government agencies, research bodies and the industry.

Preparation of a noise control by-law should be undertaken in consultation with the Ministry. After adoption by the Council, three certified copies of the by-law are forwarded to the Ministry for approval by the Minister as required by legislation.

The by-law is administered by the Noise Control Officer designated by the Council. Proper enforcement of the quantitative aspect of a by-law will require trained personnel in possession of a valid Certificate of Competency in Environmental Noise Technology.

4.0 INDUSTRIAL NOISE IMPACT ASSESSMENT

Although transportation noise is the main contributor to community noise, those exposed often develop a partial empathy towards transportation noise because they anticipate a personal use for the particular mode of transportation. In case of industrial noise, with the exception of persons whose livelihood depend upon the particular industry, a similar empathy is generally lacking. The possible tax benefits from nearby industry do not carry

much weight in a community that believes property values have decreased because of increased noise.

Furthermore, industrial noise creates adverse community reaction because of some or all of the following characteristics:

- presence of discrete tones, beats or rumble
- presence of impulsive or impact events
- rapid variation with time
- interference with sleep and speech
- conveying a fear message
- reminder of other side effects
- location of the industry in otherwise quiet environment

Community response to industrial noise depends on both the absolute sound level of intruding noise and on the increase in sound level relative to the previous ambient sound level in the community.

The variety of industrial processes is such that attempting to set emission standards for each piece of industrial equipment is generally impractical. Acceptability of industrial noise depends strongly on factors other than the noise level of the equipment. For example, the industry may be surrounded only by other industries and consequently may not be a nuisance.

A more realistic approach to industrial noise control is to set acceptable noise criteria for noise sensitive land uses and to plan future development to avoid incompatible neighbours being located adjacent to one another.

In Ontario, the essence of noise guidelines specified by the Ministry of the Environment is that no industrial

operation should generate more noise at an adjacent residential receptor location than the pre-existing vehicular traffic noise in the area in which it is located. The guideline for stationary source noise impact assessment is given by the Technical Publication NPC-105, Stationary Sources, and it applies to all built-up areas. The basic provision of this guideline is specified in Section 4.2, and applies to all types of sound, excluding impulsive sounds. An assessment of noise impact due to source operation is made in terms of one hour equivalent energy level descriptor Leq.

For impulsive sound, the general sound level limit is given in Section 4.1. The impact of noise from impulsive sources is expressed in terms of the Logarithmic Mean Impulse Sound Level L_{LM} defined in a following formula:

$$L_{LM} = 10 \log [1/N[10^{dBAI_1/10} + 10^{dBAI_2/10} + \ldots + 10^{dBAI_N/10}]]$$

where: $dBAI_1$, $dBAI_2$ ... $dBAI_N$ are the N impulse sound levels measured in dBAI.

The Hourly Equivalent Sound Level, Leq, caused by vehicular traffic at the point of reception is the applicable general sound level limit in both cases of impulsive and non-impulsive sources.

It has to be recognized that some industrial impulsive noises are of highly intrusive nature, and are annoying no matter in what kind of environment they are generated.

For these types of noise two specific sound level limits have been established, depending on the frequency of their occurrence.

The first limit set for specific industrial sources generating frequent impulsive sounds such as metal working operations (including but not limited to forging, hammering, punching, stamping, cutting, forming and moulding) is specified in Section 5.1 and is expressed in terms of the Logarithmic Mean Impulse Level descriptor, L_{LM}. The applicable limit for these sources is 60 dBAI if they were in operation before January 1, 1980, and otherwise it is 50 dBAI. A detailed procedure for the measurement of frequent impulsive sounds is described in Sections 3.4(f) of the Technical Publication NPC-103, Procedures. As a basic requirement for the calculation of L_{LM}, a minimum number of 20 impulsive events shall be measured within a continuous period of 20 minutes.

The other specific impulsive limit, set for operations generating infrequent impulsive sounds which occur as single, seemingly independent, event, is specified in Section 5.3. The applicable limit is 100 dBAI, and the procedure for such single impulsive event measurement is described in Section 3.4(g) of the Technical Publication NPC-103, Procedures.

A pre-emption is included in Section 7(1), allowing for the selection of least restrictive limits if more than one sound level limit is applicable for a particular operation.

Where limits expressed in terms of energy equivalent (Leq) sound levels are applicable to an industrial operation, an exclusion is specified in Section 8 that removes any

restriction on industrial operation generating an hourly Leq level of 40 dBA or less at the point of reception.

5.0 BLASTING NOISE AND VIBRATION IMPACT ASSESSMENT

Blasting operations at quarries and surface mines generate noise and vibration impact of a type quite different from that of transportation, industry and other high level environmental noise and vibration sources. Impact due to blasting is impulsive, relatively infrequent, often unpredictable in time of occurrence and is likely to be quite variable in level. A community may experience such exposure over long periods of time, sometimes in residences at considerable distances from the blasting site.

Air blasts or concussions may affect communities not only through the shaking of the structural elements of their residences, but directly through the auditory system causing surprise, startle, fear of damage or injury or other secondary effects.

Adverse community reaction to blast produced vibration can be expected at levels that are much lower than the thresholds established for structural damage.

The technical problems of quantifying community response to blasting events and setting applicable limits are complicated by the simultaneous presence of both air blasts, and ground vibration, and many secondary effects such as window or dish rattling.

Based on the results of extensive research carried out by various agencies, and the best current understanding of community reaction to blasting, two sets of limits have

been established by the Ministry in the Technical Publication NPC-119, Blasting, to assist in effective control of noise and vibration.

5.1 Blasting Limits

- Cautionary limit, applicable to operations not subjected to a routine monitoring.

- Standard limit, applicable to operations where a routine monitoring of noise and vibration is carried out by the quarry/mining operator.

The limits are expressed in terms of peak sound pressure level (dBLin) and peak vibration velocity (cm/s). The following limits are specified:

(i) Concussion - cautionary limit: peak pressure level of 120 dBLin;

(ii) Concussion - standard limit: peak pressure level of 128 dBLin;

(iii) Vibration - cautionary limit: peak vibration velocity of 1 cm/s;

(iv) Vibration - standard limit: peak vibration velocity of 1.25 cm/s.

A detailed procedure for the measurement of sound and vibration due to blasting operation is described in Section 5 of the Technical Publication NPC-103, Procedures.

CHAPTER 7

NOISE COMPLAINT INVESTIGATION PROCEDURE

1.0 INTRODUCTION

A noise complaint investigation may be described as the work performed to analyze and report a noise situation in order to establish compliance with Ministry's noise guidelines. The procedure for noise complaint investigation involves the following steps: receiving complaint, setting up noise complaint register, preliminary investigation, interviews with complainant and noise producer, subjective assessment of impact severity, measurement survey and report writing.

1.1 Noise Complaint Registry

A complaint registry is set up by the Noise Unit and it is used as an example. Complaints are recorded on a complaint form as shown in Figure 7.1, preferably in four copies. Each complaint form is numbered with a five digit number in sequence distinguishing it from others and to keep a running total of the number of complaints received. The first of two digits of the sequence number is the last two digits of the year, and the subsequent digits are sequential. The first complaint of the year is always numbered 001 (e.g. the first complaint in 1987 is numbered 87001).

Note: If a complaint registry is computerized, a less cumbersome registration system may be created.

Noise Complaint Form

TOWN, CITY OR MUNICIPALITY

SEQUENCE NO.	CATEGORY

INVESTIGATION NO.

WHEN RECEIVED __________ AM/PM ______________________________19____	
RECEIVED BY	LOCATION

COMPLAINANT TEL. NO. ADDRESS
SOURCE (NAME OF COMPANY OR PERSON) TEL. NO. ADDRESS
NATURE OF COMPLAINT
INVESTIGATE DECISION

COPIES TO: 1. Investigation file   2. Alphabetical register of complainants   3. Alphabetical register of sources   4. Chronological sequence of complaints register

Figure 7.1 Noise complaint registry form.

(a) Complainant Identification

The full name and initials with address, both residence and business phone numbers should be obtained if possible.

Anonymous complaints should never be accepted, as it is impossible to obtain further information from the complainant.

1.2 Nature of Complaint

Information on the alleged source of noise should be as complete as possible. Description of the nature of the complaint should include:

- Type of noise:
  - stationary (air conditioning, machinery, etc.)
  - mobile (aircraft, train, truck, etc.)
  - community (parties, radios, etc.)
- Time when the noise is present:
  - time of the day, duration, how often (every Tuesday, etc.)
- Characteristics of the noise:
  - hum, screech, buzz, etc.
- Previous action by the complainant:
  - Describe in detail.
- Time and date the complaint was received and by whom.

1.3 Cross Referencing in Complaint Recording System (Using Hard Copy Records)

Number 1 copy of the complaint form is filed in the investigator's file which is stored in numerical order of the investigation number, or in a loose leaf "NOT INVESTIGATED" register.

Number 2 copy of the complaint form is kept in a loose-leaf register in alphabetical order of the complainants surname.

Number 3 copy of the complaint form is kept in a loose-leaf register in alphabetical order of the noise source.

Number 4 copy of the complaint form is kept in a loose-leaf register by chronological sequence number.

This filing method maintains a cross-reference file system with the least amount of maintenance and only one operating file.

1.4 Noise Source Categories

The noise sources may be assigned a category as follows:

HVAC	Heating, Ventilation, Air Conditioner, Heat Pump etc.
INDP	Industrial Plant
COMB	Commercial Building
CDQM	Construction, Demolition, Quarries, Mining
REDL	Residential (other than Air Conditioners)
PRIT	Private Transportation
TRAF	Traffic in General (e.g. highway noise)

OTHR Other

RECV Recreational Vehicle

SOEJ Federal (aircraft, train, etc.)

Note: Local municipalities may want to set up other categories, such as barking dogs, parties, etc.

2.0 PRELIMINARY INVESTIGATION

The investigator will establish the general source of the noise complaint if there is or has been a previous investigation and if a complaint should be further investigated.

If there has been a previous investigation on this source in the same category, this complaint will be given the same investigation number and category.

If there is no existing investigation file, a new file will be opened and given an investigation number and category, except when there is to be no investigation, in which case the No. 1 of the complaint form will be filed in a special "NOT INVESTIGATED REGISTER".

If there is to be no investigation, the complainant must be advised in writing stating the reasons.

All four copies of the complaint form will be annotated with the investigation number of the complaint. The complaint form will then be filed in the appropriate file and register.

If the complainant is not interviewed and the investigation will take longer than two weeks, the complainant

shall so be advised either by letter or by telephone of the status of the complaint.

A written record should be made in the investigation file. On completion of the investigation, the complainant should be advised in writing.

The preliminary investigation may be sufficient to establish whether the Local Municipal Noise Control By-Law does in fact cover the situation. If it does, this visit may, in simple cases, be all that is needed to establish if the sound is excessive according to the by- law. In complex situations, subsequent investigation(s) will usually be necessary.

3.0 OUT OF JURISDICTION COMPLAINTS

If the source of the noise is not within the jurisdiction of the municipality, the complaint should be forwarded to the appropriate authority and the complainant so advised either at the time of lodging complaint or by subsequent letter.

3.1 Federal Jurisdiction Covering Problem Areas

(i) Aircraft Noise

- Pearson International Airport, Airport Noise Management Office (416) 676-4531 (Malton)

- Other Ontario airports, Ontario Navigation requirement and Systems Transport Canada (416) 224-3575 (Toronto)

(ii) Railway Noise

- o Canadian Transport Commission (CTC) Railway Transport Committee (RTC) (819) 997-4425 (Hull)

- o Canadian National Railway (CNR) (416) 860-2345

- o Canadian Pacific Railway (CPR) (416) 863-8193

- o GO Transit, Development and Special Projects Division (416) 630-5220 (Toronto)

- o Toronto Transit Commission (TTC), Marketing and Commercial Relations (416) 393-3030 (Toronto)

NOTE 1: Shunting and loading on private property should be treated as a stationary noise source.

NOTE 2: Municipal by-laws may be enacted under the Railway Act to control the blowing of the warning whistle at level crossings.

(iii) Motor Vehicle Noise

- o Provincial Highways and Freeways, Ministry of Transportation and Communications (MTC), Environmental Office (416) 235-3478 (Downsview)

- o Regional and Municipal Roads, The Regional Road Traffic Department of the Municipality

(iv) All federal concerns (Ontario Region), Environment Canada, Environmental Protection Service, Ontario Region (416) 973-5840

Only problems concerning provincial jurisdictions should be referred to the MOE District and/or Regional Offices.

4.0 INTERVIEWS

Usually the first step in a noise investigation is to contact the complainant. This will make the complainant aware that his/her complaint is being responded to and, in most cases, will enable the investigator to obtain more specific details of the complaint.

A useful procedure prior to interviewing the complainant and the noise producer is to take a "walk around" the area of the complaint. This may result in determining the actual noise source or other contributing noise sources. This survey also enables the investigator to get familiarized with the local environment and, as a result, he is in a better position to discuss the problem at initial interview with the complainant and the noise producer.

Before visiting the private residence, it is a good practice to make an advanced telephone call to the complainant to ensure that a visit is convenient and that an annoying source is audible. Should the investigator be delayed or unable to keep an appointment, it is advisable to telephone and inform the complainant of this.

At any interview the investigator should ensure that his official position and name are known by presenting his identification card.

As a number of separate items are covered in an investigation, various forms have been prepared to help the investigator obtain the information which is usually necessary to seek. These forms may be supplemented by additional

INVESTIGATION NUMBER

Date: ____________________

INVESTIGATION REPORT
COMPLAINANT INTERVIEW

NAME: ______________________________

ADDRESS: ______________________________ PHONE ____________

____

1. TYPE OF NOISE: (i) ____________
   (ii) ____________
   (iii) ____________
   (iv) ____________

2. TIME(S) OF NOISE:

Noise	Continuous Yes or No	Occasional Yes or No	Usual limits of occurrence e.g. 9 a.m. - 10 a.m.
(i)			
(ii)			
(iii)			
(iv)			

3. WHEN DID NOISE FIRST BECOME A PROBLEM? ____________

____

____

4. HAVE YOU CONTACTED NOISE PRODUCER DIRECTLY? YES ☐ NO ☐

   IF YES: WAS REACTION CO-OPERATIVE? ☐ CONCERNED? ☐

   HOSTILE? ☐

5. OTHER COMMENTS: ______________________________

____

____

Investigating officer(s): 1. ____________

2. ____________

Figure 7.2 Complainant interview form.

information at the discretion of the investigator. The forms should in any case be supplemented by maps and photographs covering the area and showing the pertinent location of the complainant and source(s).

4.1 Interview with the Complainant

The purpose of the interview is to complete the information on a complaint. The COMPLAINANT INFORMATION FORM (shown in Figure 7.2) should be completed, if possible, while with the complainant. The investigator should proceed with a line of questioning which will determine the cause of the complaint, the nature of the noise and its likely source, etc. Precise indication of the times that the noise occurs may be crucial in tracing a source. If a noise may be heard at the time of the visit, the investigator should have the complainant point it out. The investigator should also ensure that he has the correct name, title (if any) and initials of the complainant, the complete address and telephone number.

4.2 Interview with the Noise Producer

The investigator should also interview the noise producer during the course of the preliminary investigation. The investigator should always enter a plant or premises through the main entrance and identify himself with his identity card and ask for a senior company official. The investigator should then state that the purpose of his visit is to investigate a noise complaint and that he is trying to locate the noise source.

To provide some guidance in the questioning of the noise producer, the NOISE PRODUCER INTERVIEW FORM was prepared (shown in Figure 7.3).

INVESTIGATION NUMBER

Date: ____________________

INVESTIGATION REPORT

NOISE PRODUCER INTERVIEW

PREMISES KNOWN AS: ______________________________ PHONE __________

ADDRESS: ____

____

CONTACT NAME: ________________________ TITLE ____________________

1. IS THE NOISE PRODUCER AWARE THAT HE IS CAUSING A NOISE PROBLEM? YES ☐ NO ☐
   IF YES, DOES HE KNOW THE NOISE SOURCE? YES ☐ NO ☐

2. DESCRIBE THE NOISE SOURCE. IF AN AIR-CONDITIONER IN A RESIDENCE, WHAT IS THE OUTPUT, MAKE AND MODEL?
   ____
   ____

3. WHAT ARE HOURS OF OPERATION OF NOISE SOURCE(S)?
   (THIS SHOULD CONFIRM OR DENY THE COMPLAINT HOURS).
   ALSO NOTE ANY CYCLES OF OPERATION.
   ____
   ____
   ____

4. CAN EQUIPMENT BE SWITCHED ON AND OFF FOR MEASUREMENTS? YES ☐ NO ☐
   IF YES, WHEN? ______________________________

5. CAN EQUIPMENT BE SWITCHED OFF OR REDUCED IN POWER AS A WAY OF LESSENING NOISE? (e.g. AT NIGHT) YES ☐ NO ☐
   IF YES, WHEN? AND DOES INVESTIGATOR FEEL THIS MAY HELP?
   ____

6. HAS THE NOISE PRODUCER ANY FUTURE PLANS THAT MAY ABATE THIS PROBLEM? YES ☐ NO ☐
   IF YES, GIVE DETAILS INCLUDING DATES ____________________

7. WAS NOISE SOURCE OPERATING AT TIME OF VISIT? YES ☐ NO ☐

Investigation Officer(s): 1. ____________________
2. ____________________

Figure 7.3 Noise producer interview form.

It is advisable to obtain all the relevant technical data about the noise source if it can be identified during the visit.

It may sometimes be advisable not to call the suspected noise producer before the first visit. A surprise visit may indicate that a laxness in procedures is a contributing factor to the noise problem; and may prevent a quick, but temporary, rectification of the noise problem prior to the investigator's arrival.

5.0 INVESTIGATOR'S OBSERVATION REPORT

After the investigator has interviewed the complainant and the noise producer, he should make an assessment of the noise and report his findings using the INVESTIGATOR'S OBSERVATION FORM (Figure 7.4).

The assessment should include the investigator's opinion about the cause of the noise, and the magnitude of excess above the allowable limits. The assessment should clearly establish if there is a violation of by-laws or guidelines.

A map or diagram showing land use (and zoning if available) together with measurement locations should be added together with any photographs or sketches of the source that the investigator feels is necessary. A suggested form for this is presented in Figure 7.5. Relative location of complainant and the noise producer must be clearly indicated in this diagram.

INVESTIGATION NUMBER

Date: ____________

INVESTIGATION REPORT
INVESTIGATOR'S OBSERVATIONS

1. DOES NOISE HAVE AN AUDIBLE TONAL QUALITY? YES ☐ NO ☐
   IF YES, DESCRIBE ____________
2. DOES THERE SEEM TO BE A BEAT? YES ☐ NO ☐
3. DOES THERE SEEM TO BE AN IMPACT NOISE? YES ☐ NO ☐
   IF YES, DESCRIBE ____________
4. DOES THERE SEEM TO BE A VIBRATION? YES ☐ NO ☐
   IF YES, DESCRIBE ____________
5. WHAT APPEARS TO BE CAUSING THE NOISE? ____________
6. IS THE NOISE EXCESSIVE IN THE INVESTIGATOR'S OPINION? YES ☐ NO ☐
   ANY SPECIAL REASONS: ____________
7. CAN THE PROBLEM BE VERY OBVIOUSLY ABATED? YES ☐ NO ☐
   IF YES, HOW? ____________
8. WAS THE NOISE PRODUCER'S ATTENTION DRAWN
   TO THE OBVIOUS REMEDY? YES ☐ NO ☐
9. DID THE NOISE PRODUCER SEEM WILLING TO
   CO-OPERATE IN ABATING THE PROBLEM? YES ☐ NO ☐
   IF YES, HOW? ____________
10. CIRCLE CATEGORY OF PREDOMINANT NOISE: PRIT PUBT SOEJ
    HVAC INDP COMP CDOM RECV REDL OTHR

Investigation Officer(s): 1. ____________

2. ____________

Figure 7.4 Investigator's observations form.

SKETCH OF MEASUREMENT LOCATION(S)

Figure 7.5 Sketch of measurement locations.

SOUND MEASUREMENTS DATA SHEET (FULL OCTAVE BANDS AND DIFFERENT WEIGHTING NETWORKS)	DATE
	INVEST. NO.

INSTRUMENTATION			
	Make	Type	Serial No.
Sound level meter			
Microphone			
Octave analyser			
Calibrator			

MEASUREMENT CONDITIONS					
Time					
Wind Speed					
Wind Direction					
Temp.					
Precip.					
R.H. %					
Battery					
Cal.	Before				
	After				

CIRCLE THE OCTAVE BAND WHERE BEAT OCCURS

INVESTIGATORS 1. 2.					
NOISE CHARACTERISTIC					
TONAL		IMPULSE		BEAT	
YES	NO	YES	NO	YES	NO

INTERMITTENT: Observed duration in any 60 minute period		
$\leq$ 5min.	> 5 & $\leq$ 15min.	> 15min.

No.	MEASUREMENT POSITION	Pos'n on diag.	Meter Response F/S	Time	dBA	dBB	dBC	dB Lin.	dB LEVEL - O.B. CENTRE FREQUENCY (Hz.)										COMMENTS
									31.5	63	125	250	500	1K	2K	4K	8K	16K	
1																			
2																			
3																			
4																			
5																			
6																			

Figure 7.6 Sound measurements data sheet (1 octave frequency-bands).

DATE	INVEST NO.
INVESTIGATORS	1.
	2.

INSTRUMENTATION	Make	Type	Serial No.
Sound level meter			
Microphone			
1/3 Octave analyser			
Calibrator			

MEASUREMENT CONDITIONS					
Time					
Wind Speed					
Wind Direction					
Temp.					
Precip.					
R.H. %					
Battery					
Cal.	Before				
	After				

1/3 O.B. in which tone occurs is					
Hz.					
dB					
	adjacent bands		total band	adjacent bands	

	MEASUREMENT POSITION	Pos'n on diag.	Meter Response F/S	Time	dBA	dBB	dBC	dB Lin.	dB LEVEL - 1/3 O.B. CENTRE FREQUENCY (Hz.)											COMMENTS
									25	31.5	40	50	63	80	100	125	160	200	250	

		dB LEVEL - 1/3 O.B. CENTRE FREQUENCY (Hz.)																			
		315	400	500	630	800	1K	1.25K	1.6K	2K	2.5K	3.15K	4K	5K	6.3K	8K	10K	12.5K	16K	20K	

Figure 7.7 **Sound measurement data sheet (1/3 octave frequency-bands).**

6.0 MEASUREMENT SURVEY DATA COLLECTION

If measurement data is collected in the field, it is to be documented on the forms (shown in Figures 7.6 and 7.7). If needed, results of measurements using 1/1 octave-band filters and different weighting networks are recorded on the form of Figure 7.6. The form shown in Figure 7.7 is used for 1/3 octave-band measurements only and is usually employed in a subsequent investigation of a noise complaint. The important parts of these record sheets are covered below.

(i) Instrumentation

It is recommended that the serial numbers of equipment used in each investigation be noted as a matter of good practice although they may be only required when legal action is considered or in the case of suspected instrument malfunction.

(ii) Weather Conditions

The weather conditions at the time of the sound level measurement should be noted (under the heading "Precip." note "None/Rain/Snow" as applicable). Local meteorological office may provide most of this data. Outdoor measurements are not usually conducted when wind speed exceeds 16-19 km/h. Measurements are to be avoided when relative humidity is in excess of 90%.

(iii) Noise Characteristics

Indicate on the data sheet if the noise is tonal, impulsive or has a beat.

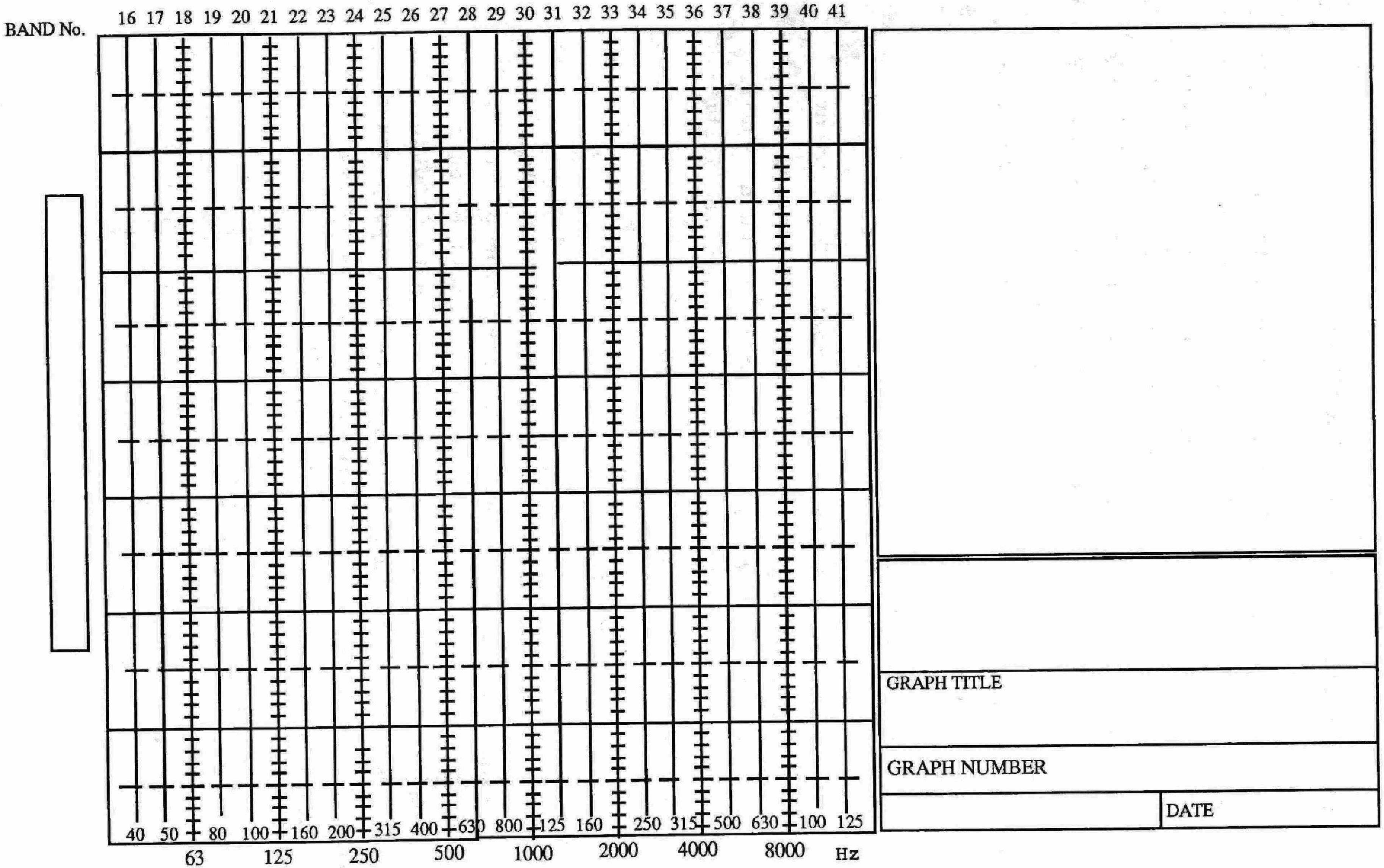


Figure 7.8 **Graph used to plot frequency spectrum of noise.**

(iv) Intermittency

The length of time the noise is 'observed' in a 60-minute period is noted under one of the three headings of less or equal to five minutes, between five and 15 minutes or more than 15 minutes.

Frequency graph of Figure 7.8 is used to plot both full octave and 1/3 octave-band measurements.

7.0 COMPLAINT STATISTICS

Keeping a record of noise complaints can result in useful statistics to answer various questions thought to be of interest either at the time the statistics are gathered or at a later date.

Some examples of useful analysis of noise complaints are:

- the number of noise complaints received per year or per month;
- the number of complaints in each noise source category;
- the geographical areas in which the complaints most occur;
- the average length of time taken to investigate a complaint;
- the number of complex and less complex investigations; and
- the number of people benefiting from noise reduction.

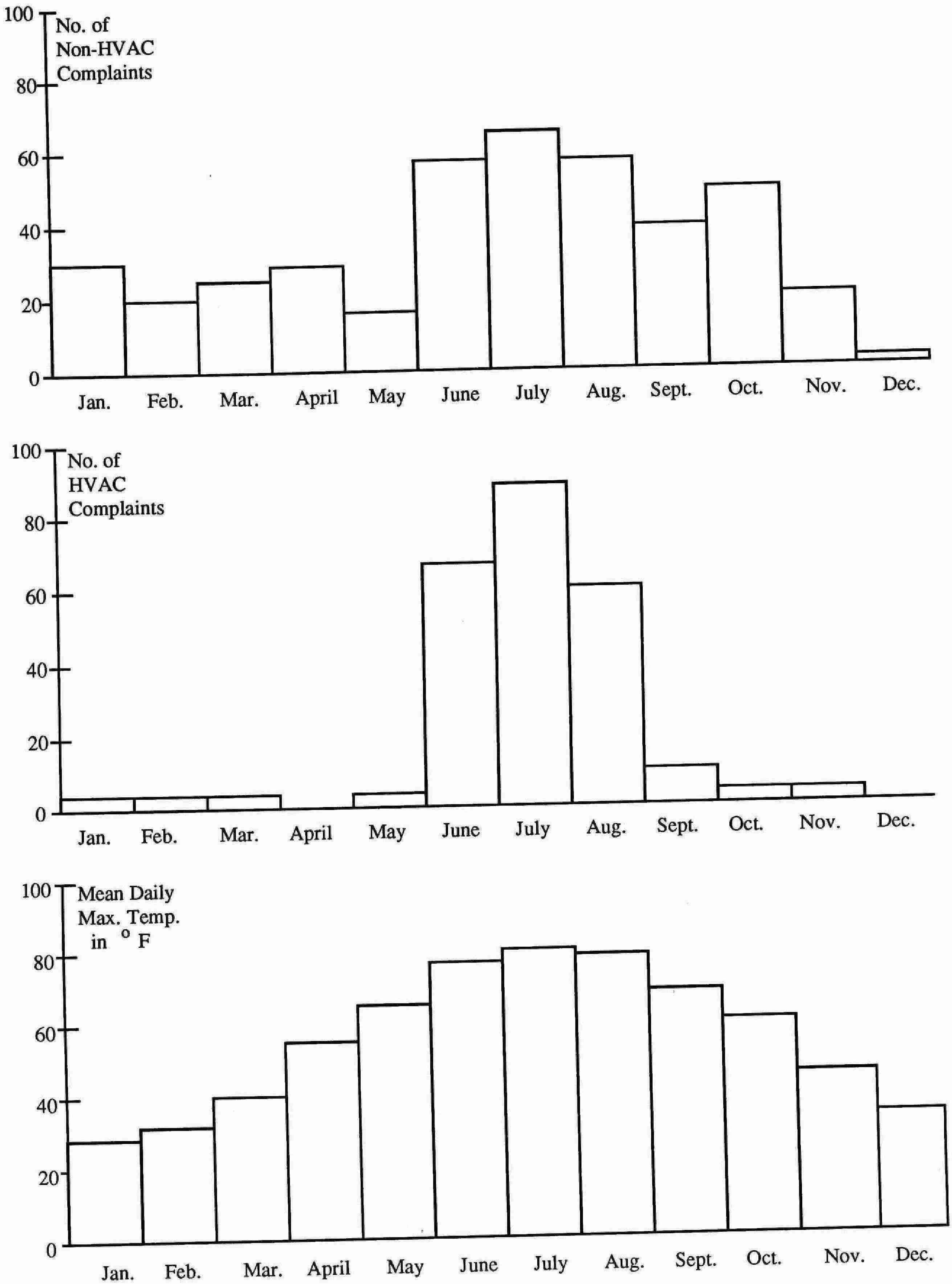


Figure 7.9 **1974 Noise Complaint Statistics of a typical municipality.**

The main purpose of most complaint statistic analysis is to provide information which will be of use in planning further manpower and instrument allocation in local noise control programs. Consider the three histograms of Figure 7.9 as an illustration. HVAC and non-HVAC complaints are shown for each month in a municipality, as well as mean daily maximum outdoor temperature. Most of HVAC complaints occur during the three warmer months - June, July and August. Non-HVAC complaints are less dependent on weather conditions, although a peak effect is also noted in the same three months. The graphs clearly indicate an increased workload in summer months and hence provide a tool in the planning of resources for noise control activity.

The statistics, when studied, will probably reveal ways in which the municipality's procedures, staff and equipment can be better directed.

The information gained from the analysis may provide an indication of the effectiveness of the noise control activities being carried out.

The information may allow problem areas to be identified and would indicate whether further action by the authorities is required.

8.0 LAYING CHARGES UNDER THE ENVIRONMENTAL PROTECTION ACT OR A MUNICIPAL NOISE BY-LAW

8.1 The complainant should find a Justice of the Peace with the appropriate jurisdiction. He should be able to find one at his local municipal building.

8.2 The complainant must lay before the Justice an information, in writing and under oath, charging the accused person with the appropriate offense.

8.3 If all the formal requirements are met, the Justice must take the information and proceed to hear the complainant's allegations. Where he considers that a case has been made out for so doing, he will set a date for a trial and issue a summons to the defendant.

8.4 At trial, the complainant is the prosecutor. In order to obtain a conviction, he will need to prove his case against the defendant beyond a reasonable doubt. The complainant should be prepared, if necessary, to subpoena a witness or witnesses.

8.5 The complainant may find it desirable to employ legal counsel or to enlist the service of a by-law officer to assist him in his prosecution. By-law officers have experience in these matters and since similar charges will often be heard on the same day, one may be in court that day anyway.

8.6 A complainant should remember that although the Judge may award costs, this is not commonly done. He will probably have to pay all the expenses of the prosecution (but not of course of the defence).

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APPENDIX A

GUIDELINES FOR ROAD TRAFFIC NOISE ASSESSMENT

GUIDELINES
FOR
ROAD TRAFFIC NOISE ASSESSMENT

ONTARIO MINISTRY OF THE ENVIRONMENT
ENVIRONMENTAL APPROVALS AND LAND USE PLANNING BRANCH
DECEMBER 1986

TABLE OF CONTENTS

1 INTRODUCTION

This report is a simplified guideline manual for the prediction of road traffic noise. It presents the procedure required by this Ministry for the prediction of equivalent sound levels, L_{eq}, due to road traffic. This procedure is to be used for land use planning, approvals of new installations or abatement.*

The prediction model is based on an enhanced and simplified version of a procedure developed by the U.S. Federal Highway Administration.** Results of studies conducted to determine the prediction accuracy of the model on Ontario roadways have indicated that, within the limitations described in Section 4, the average difference between the measured and predicted sound levels is about 2 dBA.

The manual is structured in the following manner:

> Sections 2 and 3 contain step-by-step instructions on the method used to calculate sound levels due to road traffic.
>
> Section 4 contains limitations of the prediction model in terms of traffic speed, distance, volume and topography.
>
> The final section contains a sample calculation. The calculation is performed through the use of tables and traffic noise prediction worksheets.

---

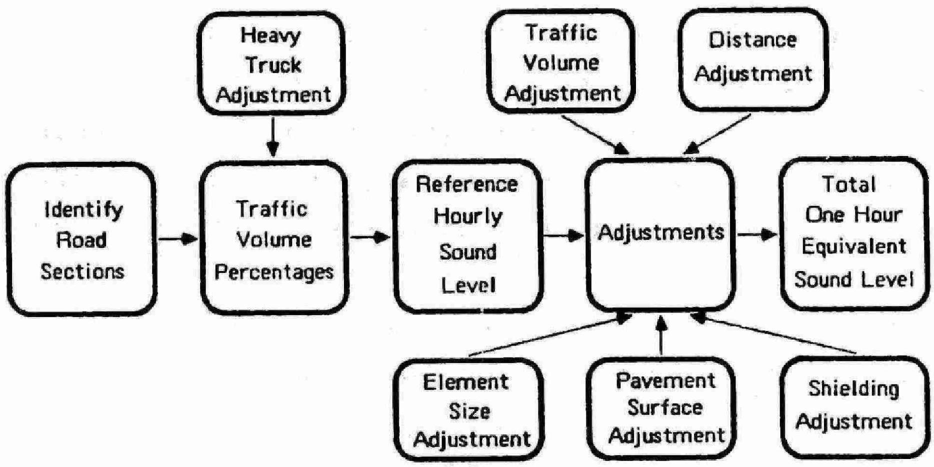
* In complex situations involving multiple roadways, multiple shielding mechanisms and/or varying topography, it is more appropriate to utilize a computer program available from the Noise Assessment Unit, Ministry of the Environment.

** Bibliography and theoretical background are contained in a separate document.

2 TRAFFIC SOUND LEVEL FOR A SINGLE ROADWAY

The following procedure shall be used to calculate the One Hour Equivalent Sound Level at a point of reception due to traffic on a single roadway. The tables used in the calculations are contained in Appendix A.

Procedure Summary



2.1 Identification of Road Sections (Elements)

(a) Where a roadway extends for large distances on either side of the point of reception, the calculation shall assume that the roadway extends, in each direction, at least six times the perpendicular distance from the point of reception to the roadway centre.

(b) A roadway of less than four lanes shall be represented by a series of straight line sections along its centre.

A roadway having a total of four lanes or more shall be divided into one or more sets of lanes for each direction of traffic flow. A maximum number of four lanes should be included in one set. Each set of lanes shall then be

represented by a series of straight line sections along its centre.

(c) A section of road shall be as long as possible but short enough to ensure that the following variables are approximately constant along its length:

- road alignment;
- road gradient (if heavy trucks are present);
- pavement surface type;
- traffic flow conditions:
  - ° total traffic volume
  - ° traffic composition
  - ° posted speed limit
- attenuation mechanisms:
  - ° ground absorption
  - ° shielding

2.2 Sound Level from a Single Road Section (Element)

The following calculations shall be used to determine the One Hour Equivalent Sound Level contribution from each road section. The method employed in deriving one hour traffic volumes from average daily traffic volumes is described in Appendix C.

(a) Traffic Volume

Traffic volumes can be obtained from the following sources:

(i) Annual MTC Reports, "Provincial Highways, Traffic Volumes" published by the Highway Program Planning Office, and "Commercial Vehicle Travel Data" published by the Transportation Demand Research Office.

(ii) Traffic Department of the local municipal office.

(iii) Individual Traffic Volume Count. Vehicles shall be counted for at least 20 minutes and the time interval of observation shall be noted. The total traffic volume, in vehicles per hour, is the number of vehicles counted divided by the time interval represented as a fraction of an hour.

If the total one hour traffic volume based on a traffic count of at least 20 minutes is less than 40 vehicles per hour, vehicles shall be counted for the full one hour period. If the full hour count is still less than 40 vehicles, this noise prediction method is not to be used.

The vehicles considered shall be placed into one of the following categories:

- Automobiles - all vehicles having two axles and four wheels designed primarily for transportation of nine or fewer passengers or transportation of light cargo (e.g. vans, light trucks). Generally, the gross vehicle weight is less than 4500 kilograms.

- Medium trucks - all vehicles having two axles and six wheels. Generally, the gross vehicle weight is greater than 4500 kilograms but less than 12,000 kilograms.

- Heavy trucks - all vehicles having three or more axles and designed for the transportation of cargo. Generally, the gross vehicle weight is greater than 12,000 kilograms. (Buses, although two axle vehicles, are included in this category).

(b) Adjusted Volume of Heavy Trucks

The adjustment shall be made by multiplying the percentage of heavy trucks travelling in the up-grade direction by an adjustment factor given in Table 1. The adjustment shall be applied only where the total vertical distance from the bottom to the top of the grade is at least 6 metres, and on roads having gradients of 2% or more. The adjusted percentage of heavy trucks shall then be converted to an adjusted volume.

(c) Percentage Trucks (Medium + Heavy)

The combined volume of vehicles classified as medium trucks and heavy trucks (adjusted if required) shall be expressed as a percentage of the total hourly traffic volume which was determined in Subsection 2.2(a).

(d) Percentage of Medium Trucks

The volume of vehicles classified as medium trucks shall be expressed as a percentage of the total volume of trucks (medium and heavy) determined in Subsection 2.2(c).

(e) Reference Hourly Sound Level

The Reference Hourly Sound Level at the reference distance of 15 metres from the centreline of the road section and the reference volume of 40 vehicles per hour shall be determined using Tables 3 through 6. Where the actual percentage of trucks (medium + heavy) is not provided, the nearest value shall be used.

(f) Measurement of Distance

The distance (in metres) between the point of reception and the centreline of the road section shall be measured along the shortest line joining the point of reception to the centre of the road section or its extension.

(g) Adjustments

The following adjustments shall be made to the Reference Hourly Sound Level.

(i) Adjustment for Traffic Volume

Table 2 gives the adjustment for traffic volume to be added to the Reference Hourly Sound Level.

(ii) Adjustment for Distance

Table 7 shall be used to adjust for distance and for the type of ground surface between the point of reception and the centreline of the road section.

"Reflective Surfaces"

Water, ice, asphalt, gravel, earth or other hard-packed surfaces are sound reflective.

If more than half of the ground surface between the centreline of the road section and the point of reception is sound reflective, the adjustment for distance and for the type of ground surface shall be determined using the section of Table 7 for Reflective Surfaces. The adjustment shall be added to the Reference Hourly Sound Level.

"Other Surfaces (Non-Reflective)"

If less than half of the ground surface between the centreline of the road section and the point of reception is sound reflective, the adjustment shall be dependent on the total effective height. The total effective height shall be determined by adding together the height of the point of reception above the ground, the effective height of shielding between the source and the receptor, (typical situations shown in Table 7), and the effective source height of road traffic obtained from Table 8. The adjustment shall be determined using the section of Table 7 for Non-Reflective Surfaces and shall be added to the Reference Hourly Sound Level.

(iii) <u>Adjustment for Road Element Size</u>

The adjustment for road element size is based on the angle subtended at the point of reception by the roadway section, see Table 10. The adjustment for road element size will also be dependent on the major type of ground surface within the sector.

<u>"Reflective Surfaces"</u>
Table 9 shall be used to determine the adjustment for road element size if more than half of the ground surface within the sector is sound reflective. The adjustment shall be added to the Reference Hourly Sound Level.

<u>"Other Surfaces (Non-Reflective)"</u>
Adjustment for Non-Reflective surfaces is considered only if the total effective height is less than 10 m. If the total effective height equals or exceeds 10 m or a barrier separates road element from receptor, adjustment in Table 9 applies.

Table 10 shall be used to determine the gular relationship between the road ion and the point of reception. Ac -ments for various combinations of angle can be determined from Table 11. The adjustment shall be added to the Reference Hourly Sound Level.

The minimum value of the adjustment equals -1 dBA which corresponds to a subtended angle of 180°.

(iv) Adjustment for Pavement Surface Type

An adjustment for the effect of road pavement surface shall be applied only on road sections having posted speed limits equal to or greater than 80 km/h. The adjustment shall be obtained from Table 12.

(v) Adjustments for Shielding

Shielding can be provided by vegetation, rows of houses or by a solid obstacle (barrier).

Dense Woods*

An adjustment for the attenuation by trees shall be made if and only if the woods are very dense, i.e. there is no visual path between the receiver and the road section (may not hold for deciduous trees in winter), and if the trees extend at least 5 metres above the line-of-sight. Table 13 gives the adjustment for shielding provided by dense woods.

Rows of Houses*

Table 13 gives the adjustment for shielding provided by rows of houses.

---

* When a receiver is shielded by dense woods or rows of houses, the ground surface must be considered "reflective".

Barriers**

Appendix B shall be used to obtain the adjustment for attenuation provided by any solid obstacle.

Combined Shielding Mechanisms

Where several types of shielding exist, the adjustments are additive up to a maximum attenuation of 20 dBA. In addition, the combined effects of dense woods and rows of houses are only additive up to a maximum of 10 dBA.

(h) Resultant Sound Level Contribution

The One Hour Equivalent Sound Level at the point of reception due to traffic on a road section is the Reference Hourly Sound Level as determined in 2.2(e) and adjusted according to 2.2(g).

2.3 Determination of Total Sound Level

The total One Hour Equivalent Sound Level at the point of reception due to traffic on a single roadway shall be determined by combining the sound level contributions from each road section using the rule for addition of sound levels in Table 14.

** Where two or more barriers intersect the line-of-sight between the source and receiver, it is a conservative practice to employ only the most effective barrier.

3 TRAFFIC SOUND LEVEL FOR MULTIPLE ROADS

The One Hour Equivalent Sound Level at a point of reception due to traffic on multiple roads shall be calculated by combining the sound levels resulting from each individual roadway as per Section 2. The individual One Hour Equivalent Sound Levels from the contributing roads shall be combined using the rule for addition of sound levels in Table 14.

4 LIMITATIONS

The method for prediction of traffic noise described herein is not applicable when:

(i) The distance from the point of reception to the centreline of any road section is less than 10 m.

(ii) The posted speed limit of traffic is less than 40 km/h.

(iii) The hourly traffic volume is less than 40 vehicles per hour.

In addition, the prediction accuracy may decrease where:

- the topography is very irregular (e.g. many different intervening man-made or natural obstructions or substantial variations in ground cover);
- the distance from the point of reception to the centreline of any road section is less than 15 m;

- the roadway has substantial variations in alignment (horizontal/vertical) or pavement surface;

- the roadway features interchanges/intersections, ramps, etc;

- substantial differences exist between the speeds of cars, medium trucks and heavy trucks.

- posted speed limit is less than 50 km/h.

It is advisible to use a comprehensive noise prediction model in the above specified cases.

5 SAMPLE CALCULATIONS

This section contains sample calculations of the One Hour Equivalent Sound Level, Leq(h), generated by road traffic. The calculations were performed through the use of tables and noise prediction work sheets.

PROBLEM

Refer to Figure 1. Using the information provided, determine the One Hour Equivalent Sound Levels, $L_{eq}(h)$, at the receiver due to traffic on the highway before and after barrier construction.

The road is flat (no gradient), infinitely long and paved with typical asphalt. The road and the surrounding terrain are at the same grade; the ground is non-reflective. The receiver is located 1.5 metres above ground. The barrier is 3 metres high.

SOLUTION

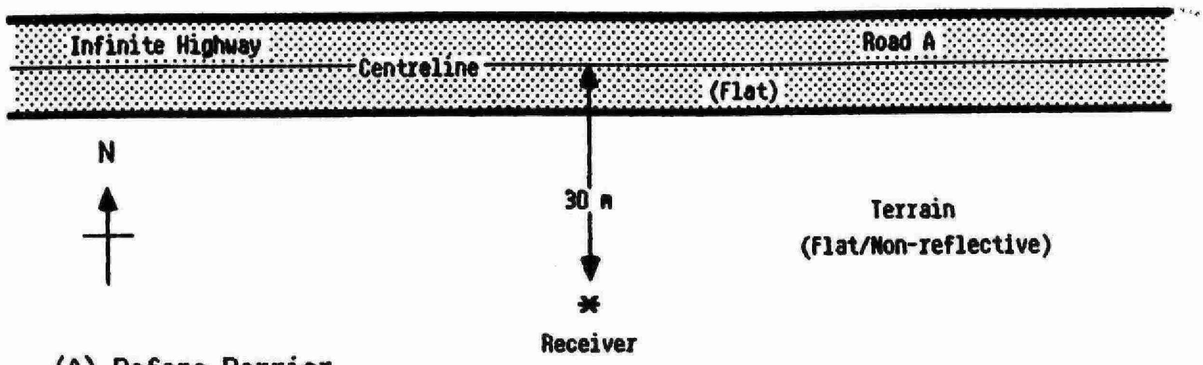
The traffic sound levels before and after the barrier is constructed have been calculated on separate work sheets. Refer to Figures 2 and 3.

5.1 Before Barrier Sound Level

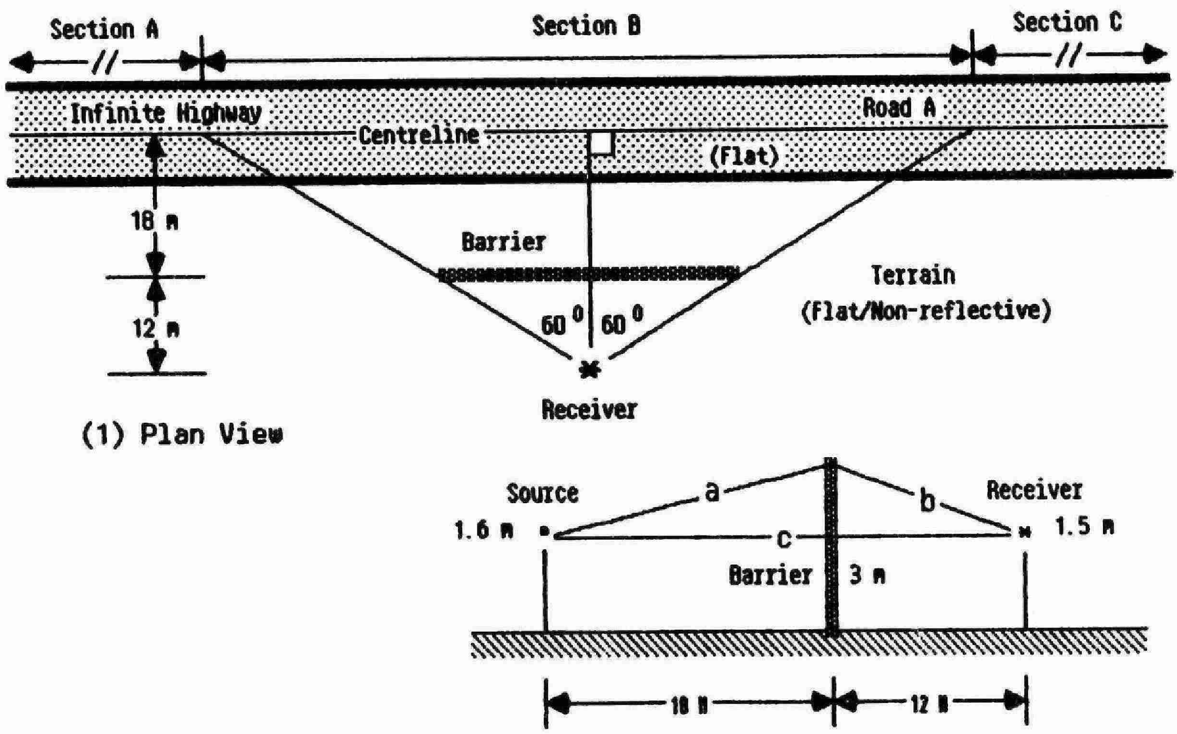
STEP 1. Since the traffic flow conditions and the characteristics of the road and of the surrounding terrain are uniform along the length of the highway under consideration, the road need not be divided into sections. Enter the appropriate lane designations for the two-lane highway on Line 1.

FIGURE 1

Conditions On Site



(A) Before Barrier



(1) Plan View

(2) Elevation View

(B) After Barrier

Vehicles Per Hour			Posted Speed (km/h)
Passenger Cars	Medium Trucks	Heavy Trucks	
910	20	70	80

(C) Traffic Data

FIGURE 2 Sample Calculation - Before Barrier

Name J. Smith Date May 5, 1986 File LU - 5001 Project Description Road A - Before Barrier

			Road A											
1	Lanes/Road Section (Element)		EB and WB											
2	Volume -Automobiles (vph)	S 2.2(a)	910											
3	Medium Trucks (vph)		20											
4	Heavy Trucks (vph)		70											
5	Total Volume (vph)		1000											
6	Posted Speed (km/h)		80											
7	Heavy Trucks (%)		7											
	Adjusted Heavy Trucks	S 2.2(b)												
8	Road Gradient (%)		0											
9	Adjustment Factor	Table 1												
10	Adjusted Volume (vph)													
11	Medium & Heavy Trucks (%)	S 2.2(c)	9											
12	Medium Trucks (%)	S 2.2(d)	22											
13	Reference Sound Level (dBA)	Tables 3-6		59										
	Effective Heights													
14	Source (s) (m)	Table 8	1.6											
15	Receiver (r) (m)		1.5											
16	Shielding (t+p) (m)	Table 7												
17	Total Effective Height (m)	Table 7	3.1											
	Adjustments													
18	Volume (dBA)	Table 2		14										
19	Distance (m)		30											
20	Reflective (dBA)	Table 7												
21	Non-reflective (dBA)	Table 7		-5										
22	Element, θ_1 (degrees)		-90											
23	θ_2 (degrees)		90											
24	Reflective (dBA)	Table 9												
25	Non-reflective (dBA)	Table 11		-1										
26	Pavement Surface (dBA)	Table 12		0										
27	Woods (dBA)	Table 13												
28	Rows Of Houses (dBA)	Table 13												
	Barrier Shielding													
29	θ_1 (degrees)													
30	θ_2 (degrees)													
31	Finite Barrier Index	Table B1												
32	Path Length Difference(m)	Table B2												
33	Barrier Attenuation (dBA)	Table B2												
34	Section Leq(h) (dBA)			67										
35	Road Leq(h) (dBA)	Table 14		67										

FIGURE 3 Sample Calculation - After Barrier

Name J. Smith Date May 5, 1986 File LU - 5001 Project Description Road A - After Barrier

			Section A				Section B				Section C			
1	Lanes/Road Section (Element)		EB and WB				EB and WB				EB and WB			
2	Volume -Automobiles (vph)	S 2.2(a)	910				910				910			
3	Medium Trucks (vph)		20				20				20			
4	Heavy Trucks (vph)		70				70				70			
5	Total Volume (vph)		1000				1000				1000			
6	Posted Speed (km/h)		80				80				80			
7	Heavy Trucks (%)		7				7				7			
	Adjusted Heavy Trucks	S 2.2(b)												
8	Road Gradient (%)		0				0				0			
9	Adjustment Factor	Table 1												
10	Adjusted Volume (vph)													
11	Medium & Heavy Trucks (%)	S 2.2(c)	9				9				9			
12	Medium Trucks (%)	S 2.2(d)	22				22				22			
13	Reference Sound Level (dBA)	Tables 3-6		59				59				59		
	Effective Heights													
14	Source (s) (m)	Table 8	1.6				1.6				1.6			
15	Receiver (r) (m)		1.5				1.5				1.5			
16	Shielding (t+p) (m)	Table 7					6							
17	Total Effective Height (m)	Table 7	3.1				9.1				3.1			
	Adjustments													
18	Volume (dBA)	Table 2		14				14				14		
19	Distance (m)		30				30				30			
20	Reflective (dBA)	Table 7												
21	Non-reflective (dBA)	Table 7		-5				-3				-5		
22	Element, θ_1 (degrees)		-90				-60				60			
23	θ_2 (degrees)		-60				60				90			
24	Reflective (dBA)	Table 9						-2						
25	Non-reflective (dBA)	Table 11		-11								-11		
26	Pavement Surface (dBA)	Table 12		0				0				0		
27	Woods (dBA)	Table 13												
28	Rows Of Houses (dBA)	Table 13												
	Barrier Shielding													
29	θ_1 (degrees)						-60							
30	θ_2 (degrees)						60							
31	Finite Barrier Index	Table B1					20							
32	Path Length Difference (m)	Table B2					.148							
33	Barrier Attenuation (dBA)	Table B2						-9						
34	Section Leq(h) (dBA)			57				59				57		
35	Road Leq(h) (dBA)	Table 14		62.5										

STEP 2. Complete Lines 2-6 and 8 from the data given in the problem statement. Complete Line 7. The heavy trucks are expressed as a percentage of total volume.

STEP 3. Determine the adjustment factor for heavy trucks on up-hill grades from Table 1. Enter the adjustment factor on Line 9 and the adjusted volume on Line 10. In the given sample calculation, the road gradient is 0% and no adjustment is required.

STEP 4. Calculate the percentage trucks (medium + heavy) (9%) as per section 2.2 (c) and enter on Line 11.

Calculate the percentage of medium trucks (22%) as per Section 2.2 (d) and enter on Line 12.

STEP 5. Determine the Reference Sound Level from Table 3, using the data shown on Lines 6, 11, and 12. Enter this reference level (59 dBA) on Line 13.

STEP 6. Determine the Effective Source Height (1.6 m) from Table 8 and enter on Line 14. Enter the Receiver Height (1.5 m) on Line 15. Enter the Total Effective Height (1.6 m + 1.5 m) on Line 17.

STEP 7. Determine the adjustment for volume from Table 2, using the volume of 1000 vehicles shown on Line 5. Enter this adjustment (14 dBA) on Line 18.

STEP 8. Complete Line 19 (30 m). Determine the adjustment for distance from the section of Table 7 for non-reflective surfaces using the data shown on Lines 17 and 19. Enter the adjustment (-5 dBA) on Line 21.

STEP 9. Refer to Table 10 and determine the angles ϕ_1 and ϕ_2. Enter $\phi_1 = -90°$ and $\phi_2 = +90°$ on Lines 22 and 23.

Determine the adjustment (-1 dBA) for road element size from Table 11 and enter on Line 25.

STEP 10. Determine the adjustment (0 dBA) for pavement surface type from Table 12 and enter on Line 26.

STEP 11. Calculate the resultant sound level, $L_{eq}(h)$ (67 dBA) and enter on Lines 34 and 35.

5.2 After Barrier Sound Level

STEP 1. As shown in Figure 1, due to the finite barrier, the highway must be divided into three sections. Refer to Table 10 and determine ϕ_1 and ϕ_2 for each section.

(i) Section A $\phi_1 = -90°$, $\phi_2 = -60°$
(ii) Section B $\phi_1 = -60°$, $\phi_2 = +60°$
(iii) Section C $\phi_1 = +60°$, $\phi_2 = +90°$

STEP 2. Enter the appropriate lane designations for Sections A, B and C on Line 1.

STEP 3. For each road section complete Lines 2-15. The entries are identical to those recorded in Section 5.1.

(i) Section A

STEP 1. Complete Lines 17-21 and 26. The entries are identical to those recorded in Section 5.1.

STEP 2. Enter $\phi_1 = -90°$ and $\phi_2 = -60°$ on Lines 22 and 23. Determine the adjustment (-11 dBA) for road element size from Table 11 and enter on Line 25.

STEP 3. Calculate the resultant sound level Leq(h) (57 dBA) and enter on Line 34.

(ii) <u>Section B</u>

STEP 1. Refer to Table 7 and enter the effective height of shielding (t + p = 6 m) on Line 16. Determine the Total Effective Height (9.1 m) and enter on Line 17.

STEP 2. Complete Lines 18, 19 and 26. The entries are identical to those recorded in Section 5.1.

STEP 3. Determine the adjustment (-3 dBA) for distance from Table 7 using the data shown on Lines 17 and 19. Enter the adjustment on Line 21.

STEP 4. Enter ϕ_1 = -60° and ϕ_2 = + 60° on Lines 22 and 23. Determine the adjustment (-2 dBA) for road element size from Table 9 and enter on Line 24.

STEP 5. Enter ϕ_1 = 60° and ϕ_2 = +60° on Lines 29 and 30. Determine the Finite Barrier Index (20) from Table B1 and enter on Line 31.

Determine the Path Length Difference (0.148 m) using the figure and formula in Table B2 and enter on Line 32.

Determine the Barrier Attenuation (-9 dBA) from Table B2 and enter on Line 33.

STEP 6. Calculate the resultant sound level Leq(h) (59 dBA) and enter on Line 34.

(iii) <u>Section C</u>

STEP 1. Complete Lines 17-21 and 26. The entries are identical to those recorded in Section 5.1.

STEP 2. Enter ϕ_1 = +60° and ϕ_2 = +90° on Lines 22 and 23. Determine the adjustment (-11 dBA) for road element size from Table 11 and enter on Line 25.

STEP 3. Calculate the resultant sound level Leq(h) (57 dBA) and enter on Line 34.

(iv) Combined Sound Level

Calculate the combined Leq(h) (62.5 dBA) for road Sections A, B and C using the rule for addition of sound levels in Table 14. Enter the road L_{eq}(h) on Line 35.

5.3 Barrier Insertion Loss

The net reduction in the traffic sound level provided by a barrier is called the Barrier Insertion Loss (BIL), i.e.

BIL = Level (Before) - Level (After)

In this problem, the barrier insertion loss is 4.5 dBA (67 - 62.5).

Note: The barrier attenuation and the barrier insertion loss are identical only if (a) the barrier shields the entire roadway and (b) the ground surface between the source and the receiver is "sound reflective".

APPENDIX A

TRAFFIC NOISE PREDICTION TABLES

TABLE 1

Adjustment to Percentage of Heavy Trucks on Up-Hill Grades

Road Gradient %	Adjustment Factor (Multiplicative)
0 to less than 2	1
2 to less than 5	1.5
5 to less than 7	2
Over 7	3

TABLE 2

Adjustment to the Reference Hourly Sound Level for Traffic Volume

Use the nearest listed value when the actual value of volume is not listed.

Hourly Traffic Volume	Adjustment (Additive) dBA	Hourly Traffic Volume	Adjustment (Additive) dBA	Hourly Traffic Volume	Adjustment (Additive) dBA
40	0	315	9	2000	17
50	1	400	10	2500	18
63	2	500	11	3150	19
80	3	630	12	4000	20
100	4	800	13	5000	21
125	5	1000	14	6300	22
160	6	1250	15	8000	23
200	7	1600	16	10000	24
250	8				

Given the posted speed limit of traffic in km/h and the total percentage of trucks (including medium and heavy trucks), the following Tables 3 and 4 provide the predicted Reference Hourly Sound Level at 15 m from the centreline of a road section with a total traffic volume of 40 vehicles per hour (vph). Use the nearest listed value when the actual value of speed or truck percentage is not listed.

TABLE 3

Reference Hourly Sound Level in dBA at 15 m and 40 vph:
Percentage of Medium Trucks in the Range of 0 - 25 %.

POSTED SPEED km/h	PERCENTAGE TRUCKS (MEDIUM+HEAVY)													
	1	2	4	6	9	12	16	21	26	35	45	60	80	100
40	48	49	51	53	54	55	57	58	59	60	61	62	63	64
50	50	51	53	54	56	57	58	59	60	61	62	63	65	66
60	52	53	55	56	57	58	59	60	61	62	63	65	66	67
70	54	55	56	57	58	59	60	61	62	63	65	66	67	68
80	55	56	57	58	59	60	61	62	63	64	65	67	68	69
90	56	57	58	59	60	61	62	63	64	65	66	67	69	69
100	57	58	59	60	61	62	63	64	65	66	67	68	69	70

TABLE 4

Reference Hourly Sound Level in dBA at 15 m and 40 vph:
Percentage of Medium Trucks in the Range of 26 - 50 %.

POSTED SPEED km/h	PERCENTAGE TRUCKS (MEDIUM+HEAVY)													
	1	2	4	6	9	12	16	21	26	35	45	60	80	100
40	47	49	51	52	53	54	56	57	57	59	60	61	62	63
50	50	51	53	54	55	56	57	58	59	60	61	62	64	65
60	52	53	54	55	56	57	59	60	60	62	63	64	65	66
70	53	54	56	57	58	59	60	61	61	63	64	65	66	67
80	55	56	57	58	59	60	61	62	62	64	65	66	67	68
90	56	57	58	59	60	61	62	63	63	65	65	67	68	69
100	57	58	59	60	61	62	63	63	64	65	66	67	69	69

Given the posted speed limit of traffic in km/h and the total percentage of trucks (including medium and heavy trucks), the following Tables 5 and 6 provide the predicted Reference Hourly Sound Level at 15 m from the centreline of a road section with a total traffic volume of 40 vehicles per hour (vph). Use the nearest value when the actual value of speed or truck percentage is not listed.

TABLE 5

Reference Hourly Sound Level in dBA at 15 m and 40 vph: Percentage of Medium Trucks in the Range of 51 - 75 %.

POSTED SPEED km/h	PERCENTAGE TRUCKS (MEDIUM+HEAVY)													
	1	2	4	6	9	12	16	21	26	35	45	60	80	100
40	47	48	50	51	52	53	54	55	56	57	58	59	61	62
50	49	50	52	53	54	55	56	57	58	59	60	61	62	63
60	51	52	53	54	56	56	57	58	59	60	61	63	64	65
70	53	54	55	56	57	58	59	60	60	62	63	64	65	66
80	55	55	56	57	58	59	60	61	62	63	64	65	66	67
90	56	57	58	58	59	60	61	62	63	64	65	66	67	68
100	57	58	59	59	60	61	62	63	63	65	65	67	68	69

TABLE 6

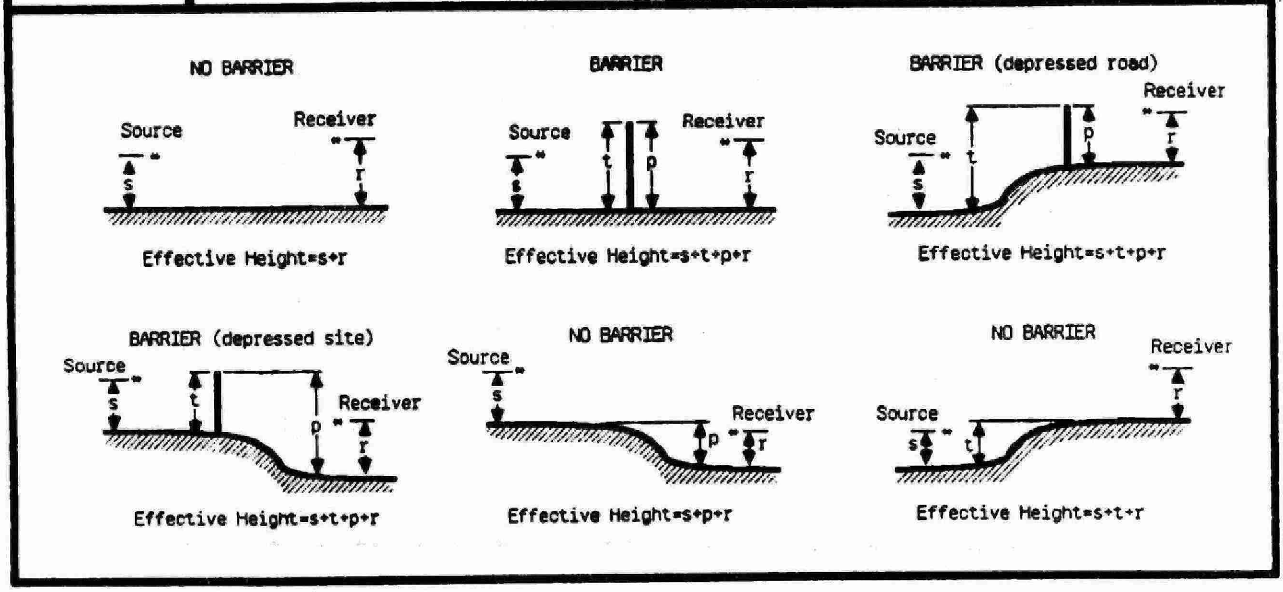
Reference Hourly Sound Level in dBA at 15 m and 40 vph: Percentage of Medium Trucks in the Range of 76 - 100 %.

POSTED SPEED km/h	PERCENTAGE TRUCKS (MEDIUM+HEAVY)													
	1	2	4	6	9	12	16	21	26	35	45	60	80	100
40	46	47	48	49	50	51	52	53	54	55	56	57	58	59
50	49	50	51	52	53	53	54	55	56	57	58	59	60	61
60	51	52	53	53	54	55	56	57	58	59	60	61	62	63
70	53	53	54	55	56	57	58	58	59	60	61	62	63	64
80	54	55	56	56	57	58	59	60	60	61	62	64	65	66
90	56	56	57	58	59	59	60	61	62	63	64	65	66	67
100	57	57	58	59	60	60	61	62	63	64	65	66	67	68

TABLE 7

Adjustment for Distance from Centreline of Road to Point of Reception

Total Effective Height (m)	Perpendicular Distance from Centreline of Road to Point of Reception (m)													
	10*	15	20	30	40	50	60	80	100	120	150	200	250	500
	Adjustment in dBA for Reflective Surfaces													
All Heights	2	0	-1	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-15
Height	Adjustment in dBA for Non-Reflective Surfaces													
1.5	3	0	-2	-5	-6	-8	-9	-11	-12	-14	-15	-17	-18	-23
2	3	0	-2	-5	-6	-8	-9	-11	-12	-14	-15	-17	-18	-23
3	3	0	-2	-5	-6	-8	-9	-11	-12	-14	-15	-17	-18	-23
4	3	0	-2	-4	-6	-7	-9	-10	-12	-13	-14	-16	-17	-22
6	2	0	-2	-4	-5	-7	-8	-9	-11	-12	-13	-14	-16	-20
8	2	0	-1	-3	-5	-6	-7	-8	-9	-10	-11	-13	-14	-17
10	2	0	-1	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-15
12	2	0	-1	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-15
16	2	0	-1	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-15
20	2	0	-1	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-15
25	2	0	-1	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-15
32	2	0	-1	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-15
40	2	0	-1	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-15
50	2	0	-1	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-15
60	2	0	-1	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-15



* Prediction accuracy decreases for distances less than 15 m from road centre.

TABLE 8

Effective Source Height of Road Traffic

Unadjusted Percentage of Heavy Trucks in Total Flow (%)	Effective Source Height (m)
0	0.5
1	1.0
2	1.2
3	1.3
4	1.4
5	1.5
6-7	1.6
8-9	1.7
10-11	1.8
12-14	1.9
15-17	2.0
18-21	2.1
22-25	2.2
26-30	2.3
>30	2.4

TABLE 9

Adjustment for Road Element Size: Reflective Surfaces

Subtended Angle ø (degrees)	Adjustment (dBA)	Subtended Angle ø (degrees)	Adjustment (dBA)
180	0	50	-6
160	-1	45	-6
140	-1	40	-7
120	-2	35	-7
100	-3	30	-8
90	-3	25	-9
80	-4	20	-10
70	-4	15	-11
60	-5	10	-13
55	-5	5	-16

TABLE 10

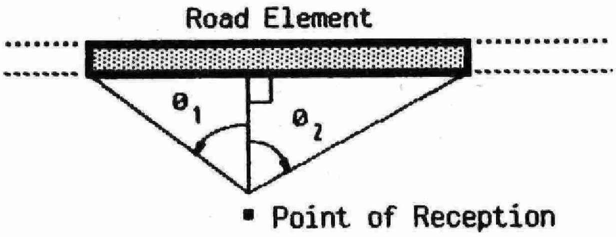
Angular Relationship between Road Elements and Receptor Locations

This table defines the angular relationship between a roadway element and a point of reception (observer) in terms of angles θ_1 and θ_2, expressed in degrees.

CASE 1

θ_1 is negative

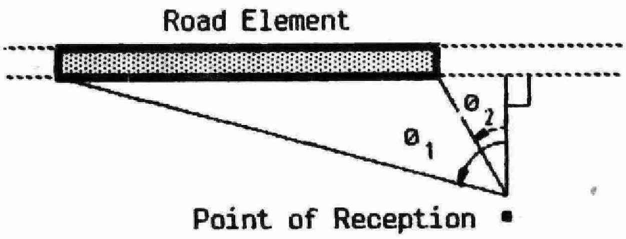
θ_2 is positive



CASE 2

θ_1 is negative

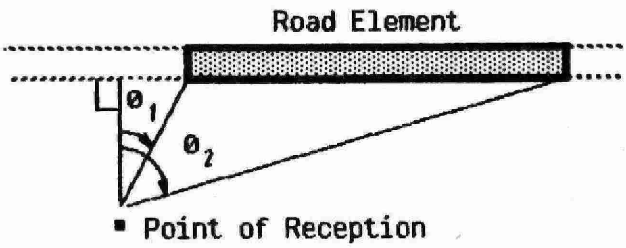
θ_2 is negative



CASE 3

θ_1 is positive

θ_2 is positive



SUBTENDED ANGLE of the road element at the point of reception:

$$\theta = \theta_2 - \theta_1$$

TABLE 11

Adjustment for Road Element Size: Non-Reflective Surfaces

LEFTMOST ROAD ANGLE, θ_1	RIGHTMOST ROAD ANGLE, θ_2																		
	-90	-80	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90
	Adjustment in dBA																		
-90	-	-18	-14	-11	-9	-8	-7	-6	-5	-4	-4	-3	-3	-2	-2	-2	-1	-1	-1
-80	-	-	-16	-12	-10	-8	-7	-6	-5	-4	-4	-3	-3	-2	-2	-2	-2	-1	-1
-70	-	-	-	-14	-11	-9	-8	-6	-6	-5	-4	-4	-3	-3	-2	-2	-2	-2	-1
-60	-	-	-	-	-14	-10	-9	-7	-6	-5	-4	-4	-3	-3	-2	-2	-2	-2	-2
-50	-	-	-	-	-	-13	-10	-8	-7	-6	-5	-4	-4	-3	-3	-2	-2	-2	-2
-40	-	-	-	-	-	-	-13	-10	-8	-7	-6	-5	-4	-4	-3	-3	-3	-2	-2
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-20	-	-	-	-	-	-	-	-	-13	-10	-8	-7	-6	-5	-4	-4	-4	-3	-3
-10	-	-	-	-	-	-	-	-	-	-13	-10	-8	-7	-6	-5	-4	-4	-4	-4
0	-	-	-	-	-	-	-	-	-	-	-13	-10	-8	-7	-6	-5	-5	-4	-4
10	-	-	-	-	-	-	-	-	-	-	-	-13	-10	-8	-7	-6	-6	-5	-5
20	-	-	-	-	-	-	-	-	-	-	-	-	-13	-10	-8	-7	-6	-6	-6
30	-	-	-	-	-	-	-	-	-	-	-	-	-	-13	-10	-9	-8	-7	-7
40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-13	-10	-9	-8	-8
50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-14	-11	-10	-9
60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-14	-12	-11
70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-16	-14
80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-18
90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

TABLE 12

Adjustment for Pavement Surface Type

Pavement Surface Type	Adjustment (dBA)
Typical asphalt pavement such as HL-1	0
Open-graded friction course	-2.5
Dense-graded friction course	-1.5
Smooth concrete pavement	-1
* New concrete pavement, wire brush finish	+6
* Grooved concrete pavement	+7

* Not used on new highways

TABLE 13

Adjustment for Dense Woods and Rows of Houses

DENSE WOODS	
Depth of Woods between Source and Receiver (m)	Attenuation (dBA)
30	5
60	10
NOTE: Maximum attenuation allowed is 10 dBA	
FIRST ROW OF HOUSES	
Percentage of Row Occupied by Houses	Attenuation (dBA)
<40	0
40-65	3
65-90	5
>90	that of a barrier
ADDITIONAL ROWS OF HOUSES	
Apply attenuation of 1.5 dBA for each successive row up to a maximum of 10 dBA.	

TABLE 14

Addition of Sound Levels

Difference Between Higher and Lower Sound Levels (dBA)	To Obtain the Sum of Two Sound Levels, Add this Value to the Higher Level (dBA)
0	3.0
0.5	3.0
1.0	2.5
1.5	2.5
2.0	2.0
2.5	2.0
3.0	2.0
4.0	1.5
5.0	1.0
6.0	1.0
7.0	1.0
8.0	1.0
9.0	0.5
10.0	0
11.0	0
12.0	0
13.0 and up	0

APPENDIX B

CALCULATION OF BARRIER ATTENUATION

A "barrier" is any solid obstacle, natural or man made which interrupts the line of sight between the observer and the roadway.

Barriers include such items as elevated/depressed sections of roadway, large buildings, solid rows of townhouses, existing topographical features, earth berms, walls and fences. All of these obstructions may reduce noise generated by road traffic.

The following procedure is used to determine the attenuation of traffic noise provided by barriers of all types. This attenuation is commonly referred to as "barrier attenuation". The barrier is assumed to be parallel to the roadway and to obstruct the observer's view of the road. Calculations for finite and infinite length barriers are contained within this procedure.

STEP 1. Determine Barrier Extent

Determine ϕ_1 (the leftmost end angle of the barrier) and ϕ_2 (the rightmost end angle of the barrier). For Example, for infinite barriers ϕ_1 is -90° and ϕ_2 is +90.

STEP 2. Determine Finite Barrier Index

Determine the Finite Barrier Index (FBI) from Table B1, using the values of ϕ_1 and ϕ_2.

For example, FBI is 9 for an infinitely long barrier.

STEP 3. Determine Path Length Difference

Determine the Path Length Difference (PLD), according to the figure and formula shown in Table B2.

It must be noted that 'D_{SB}' and 'D_{BR}' are horizontal distances; therefore, the sum of D_{SB} and D_{BR} shall not be necessarily equal to the actual source-receiver separation distance.

Path Length Difference shall be calculated to an accuracy of at least 0.001 metres.

STEP 4. Obtain Barrier Attenuation

Determine the appropriate barrier attenuation* from Table B2, using the values of PLD and FBI.

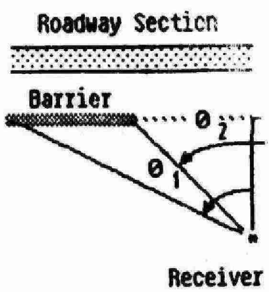
* The calculated barrier attenuation is accurate to ± 1.0 dBA, usually on the conservative side. The error in the barrier attenuation obtained from the table can be as high as 4 dBA for large values of PLD and acute angles of the barrier element. Such cases are: PLD greater than 4.0 m, ϕ_2-ϕ_1 less than 30° and ϕ_1 less than -70° or ϕ_2 more than +80°. In these circumstances the barrier attenuation could be under predicted by as much as 4 dBA. Nevertheless, this error has no appreciable influence on the overall result as the contributions from the remaining road elements dominate the resultant traffic noise level at the receiver.

TABLE B1

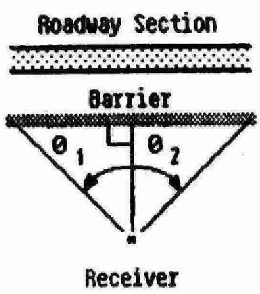
Finite Barrier Index for Asymmetric Barriers

θ_1, The Leftmost End Angle of the Barrier (degrees)	θ_2, The Rightmost End Angle of the Barrier (degrees): -80	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90
-90	1	2	3	4	6	7	9	9	9	10	12	12	12	12	14	12	12	9
-80	-	5	8	10	10	14	15	15	18	18	19	19	19	19	19	19	18	12
-70	-	-	10	11	15	15	18	19	19	19	19	19	19	19	19	19	19	12
-60	-	-	-	15	18	19	19	19	20	20	20	20	20	20	20	19	19	14
-50	-	-	-	-	19	20	20	20	21	21	23	23	21	21	20	19	19	12
-40	-	-	-	-	-	20	21	23	23	23	23	23	23	21	20	19	19	12
-30	-	-	-	-	-	-	23	23	23	23	23	23	23	23	20	19	19	12
-20	-	-	-	-	-	-	-	23	23	23	23	23	23	23	20	19	19	12
-10	-	-	-	-	-	-	-	-	24	24	23	23	23	21	20	19	18	10
0	-	-	-	-	-	-	-	-	-	24	23	23	23	21	20	19	18	9
10	-	-	-	-	-	-	-	-	-	-	23	23	23	20	19	19	15	9
20	-	-	-	-	-	-	-	-	-	-	-	23	21	20	19	18	15	9
30	-	-	-	-	-	-	-	-	-	-	-	-	20	20	19	15	14	7
40	-	-	-	-	-	-	-	-	-	-	-	-	-	19	18	15	10	6
50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	11	10	4
60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	8	3
70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	2
80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1

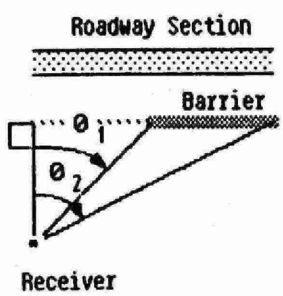
Angular Relationship between Barrier Sections and the Receiver



θ_1 is negative
θ_2 is negative



θ_1 is negative
θ_2 is positive



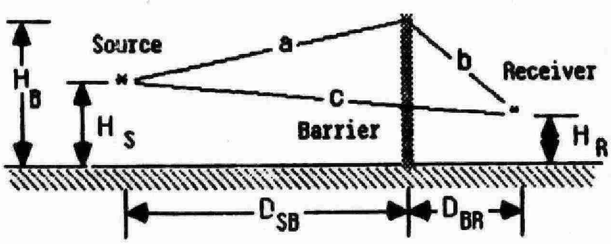
θ_1 is positive
θ_2 is positive

NOTES: 1) Where angles are not found in the table use the nearest listed value.

TABLE B2

Barrier Attenuation for Various Values of Finite Barrier Index

	Path Length Difference (m)	Finite Barrier Index 1	2	3	4	5	6	7	8	9	10	11	12	14	15	18	19	20	21	23	24
		Barrier Attenuation (dBA)																			
Barrier does not interrupt the line of sight	0.34	3	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.17	4	3	2	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
	0.07	5	4	4	4	4	3	3	3	2	2	2	1	1	1	1	1	1	1	0	0
	0.05	5	5	4	4	4	4	4	4	3	3	3	3	3	3	3	3	2	2	2	1
	0.03	5	5	5	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3
	0.02	5	5	5	5	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	0.00	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Barrier Does Interrupt the Line of Sight	0.03	5	5	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7
	0.10	5	6	6	6	6	7	7	7	7	7	7	7	7	8	8	8	8	8	9	9
	0.17	6	6	7	7	7	7	7	7	8	8	8	8	8	9	9	9	9	10	10	11
	0.24	6	6	7	7	7	8	8	8	9	9	9	9	9	9	10	10	10	11	11	12
	0.28	6	7	8	8	8	9	9	9	9	9	9	10	10	10	10	11	11	12	12	12
	0.34	6	7	8	8	8	9	9	9	10	10	10	10	10	11	11	12	12	13	13	13
	0.52	7	8	8	9	9	10	10	10	11	11	12	12	12	12	13	13	14	14	14	15
	0.69	7	8	9	10	10	10	11	11	12	12	13	13	13	13	14	14	15	15	16	16
	1.03	8	9	10	11	12	12	12	13	13	14	14	14	15	15	15	16	17	17	18	18
	1.38	9	10	11	12	13	13	13	14	14	15	15	15	16	16	17	17	18	18	19	19
	1.70	9	11	12	13	14	14	14	15	15	16	16	16	17	17	18	18	19	19	20	20
	2.06	10	11	13	14	14	14	15	16	16	16	16	16	17	18	18	19	20	20	20	20
	2.75	11	13	14	15	15	15	16	16	16	17	17	17	18	19	19	19	20	20	20	20
	3.44	11	13	14	15	16	16	16	17	17	18	18	18	18	19	19	20	20	20	20	20
	5.16	12	14	15	16	17	17	17	18	18	18	18	18	19	20	20	20	20	20	20	20
	6.88	13	15	16	17	17	18	18	18	18	19	19	19	19	20	20	20	20	20	20	20



Barrier, Source and Receiver Configuration

PLD = a + b - c

Where

$$a = \sqrt{D_{SB}^{2} + (H_B - H_S)^2}$$

$$b = \sqrt{D_{BR}^{2} + (H_B - H_R)^2}$$

$$c = \sqrt{(D_{SB} + D_{BR})^2 + (H_S - H_R)^2}$$

NOTE: 1) Where the calculated PLD is not found in the table use the nearest listed value.

APPENDIX C

COMPUTATION OF $L_{EQ}(T)$

(BASED ON DAILY TRAFFIC VOLUMES)

In the planning of noise sensitive developments or of projects such as roads or industries, dependent on the application, traffic sound levels must be determined: (a) over a 24-hour period; (b) over a day or night time period or (c) on an hourly basis.

In many cases, the provincial/municipal traffic department may not be able to provide traffic data based on surveys conducted over specific time periods of the 24-hour day.

The following describes the method which may be used to determine the equivalent sound level, L_{eq}, due to road traffic over various time periods of the 24-hour day using the information on average daily traffic provided by the road authority.

1. Information Requirements

The road authority should be contacted for the following data:

(a) Average Annual Daily Traffic Volume (AADT) and when available the Summer Average Daily Traffic Volume (SADT); use the higher of AADT or SADT;

(b) Composition of traffic, i.e. the percentage of vehicles classified by the model as automobiles, medium trucks and heavy trucks; and

(c) Posted Speed Limit (km/h)

Future traffic volumes should be based on traffic projections at least 10 years after completion of the project or the ultimate capacity indicated by the road authority.

2. Method of Calculation

2.1 Method 1: Through Adjustments made to Existing/Future Traffic Volumes

Since the model predicts the equivalent sound level, L_{eq}, due to road traffic over a 1-hour time period, the average daily traffic volume (higher of AADT or SADT) must be reduced to a one-hour volume for the time period considered.

The following one-hour traffic volumes (existing/future) must be employed in calculating:

(a) Daily Sound Level (24-hours)

$$\text{volume (1 hr)} = \frac{\text{avg. daily volume}}{24}$$

(b) Daytime Sound Level (07:00 to 23:00)

$$\text{volume (1 hr)} = \frac{\text{avg. daily volume}}{16} \times T_D$$

Where: T_D = fraction of daily volume during daytime period

(c) Night-time Sound Level (23:00 to 7:00)

$$\text{volume (1 hr)} = \frac{\text{avg. daily volume}}{8} \times T_N$$

Where: T_N = fraction of daily volume during nighttime period

(d) Hourly Sound Level

$$\text{volume (1 hr)} = \frac{\text{avg. daily volume}}{1} \times T_H$$

Where: T_H = fraction of daily volume during a one hour period

When determining the traffic sound levels over various periods of the 24-hour day, the user must, of course, employ the estimated percentage of cars, medium trucks and heavy trucks which occur during the period under consideration.

2.2 Method 2: Through Adjustments made to Sound Levels - L_{eq} (24 hr)

This method may be used to determine the equivalent sound level, L_{eq}, due to road traffic over different time periods provided the traffic composition during the period under consideration does not vary greatly from the composition averaged over the entire 24-hour day.

(1) Adjustment for Period of Day

Once the existing/future traffic sound level, L_{eq} (24 hr), has been determined the following expression may be used to obtain:

(a) L_{eq} (16 hr) = Daytime Sound Level

$$L_{eq} \text{ (16 hr)} = L_{eq} \text{ (24 hr)} + 10 \text{ Log } (24/16) + 10 \text{ Log } (x)$$

(b) L_{eq} (8 hr) - Nighttime Sound Level

$$L_{eq} \text{ (8 hr)} = L_{eq} \text{ (24 hr)} + 10 \text{ Log } (24/8) + 10 \text{ Log } (x)$$

(c) L_{eq} (1 hr) - Hourly Sound Level

$$L_{eq} \text{ (1 hr)} = L_{eq} \text{ (24 hr)} + 10 \text{ Log } (24) + 10 \text{ Log } (x)$$

In the above expressions,

x = fraction of daily volume during the period considered

(2) Adjustments for Future Sound Levels

The future sound level, $L_{eq}(T)$, for any time period T of the 24-hour day may be obtained through application of an adjustment (in decibels) to the existing sound level.

The future sound level is given by the expression:

$$L_{eq}(T)_F = L_{eq}(T)_E + 10 \text{ Log } (1 + R)^N$$

Where:

R = Annual rate of change in traffic volume (a fraction)

N = Projected time period (in years)

The above method for determining future sound levels may be used only if there is no significant difference between the fraction of the existing daily traffic volume and that of the future daily traffic volume for the period of the 24-hour day under consideration.

3. Examples of Typical Variations in Traffic Sound Levels During the Day and Night Time Period

(a) Arterial Roads

On most arterial roads the major portion of the daily (24 hour) traffic volume, about 90%, tends to occur during the daytime period (07:00 to 23:00).

The following expressions indicate the approximate relationships between the equivalent sound levels over the day/night time periods and the 24-hour equivalent sound level.

$$L_{eq} \text{ (16 hr)} = L_{eq} \text{ (24 hr)} + 1 \qquad \text{(day)}$$

$$L_{eq} \text{ (8 hr)} = L_{eq} \text{ (24 hr)} - 5 \qquad \text{(night)}$$

(b) Highways

The typical split between traffic volumes during the day and night time periods on highways is about 85% (day) and 15% (night).

The equivalent sound levels for these respective time periods are given by:

$$L_{eq}\ (16\ \text{hr}) = L_{eq}\ (24\ \text{hr}) + 1 \qquad \text{(day)}$$

$$L_{eq}\ (8\ \text{hr}) = L_{eq}\ (24\ \text{hr}) - 3.5 \qquad \text{(night)}$$

(c) Freeways (Controlled Access)

On sites adjacent to most freeways no significant differences are considered between the equivalent sound levels measured over the 16 hour daytime and 8 hour nighttime periods.

APPENDIX D
TRAFFIC NOISE
PREDICTION WORK SHEET

TRAFFIC NOISE PREDICTION WORK SHEET

Name ____________ Date ____________ File ____________ Project Description ______________________________

1	Lanes/Road Section (Element)														
2	Volume -Automobiles (vph)	S 2.2(a)													
3	Medium Trucks (vph)														
4	Heavy Trucks (vph)														
5	Total Volume (vph)														
6	Posted Speed (km/h)														
7	Heavy Trucks (%)														
	Adjusted Heavy Trucks	S 2.2(b)													
8	Road Gradient (%)														
9	Adjustment Factor	Table 1													
10	Adjusted Volume (vph)														
11	Medium & Heavy Trucks (%)	S 2.2(c)													
12	Medium Trucks (%)	S 2.2(d)													
13	Reference Sound Level (dBA)	Tables 3-6													
	Effective Heights														
14	Source (s) (m)	Table 8													
15	Receiver (r) (m)														
16	Shielding (t+p) (m)	Table 7													
17	Total Effective Height (m)	Table 7													
	Adjustments														
18	Volume (dBA)	Table 2													
19	Distance (m)														
20	Reflective (dBA)	Table 7													
21	Non-reflective (dBA)	Table 7													
22	Element, θ_1 (degrees)														
23	θ_2 (degrees)														
24	Reflective (dBA)	Table 9													
25	Non-reflective (dBA)	Table 11													
26	Pavement Surface (dBA)	Table 12													
27	Woods (dBA)	Table 13													
28	Rows Of Houses (dBA)	Table 13													
	Barrier Shielding														
29	θ_1 (degrees)														
30	θ_2 (degrees)														
31	Finite Barrier Index	Table B1													
32	Path Length Difference (m)	Table B2													
33	Barrier Attenuation (dBA)	Table B2													
34	Section Leq(h) (dBA)														
35	Road Leq(h) (dBA)	Table 14													

APPENDIX B

ADJUSTMENT PROCEDURES FOR OUTDOOR SOUND REFLECTION

ADJUSTMENT PROCEDURES FOR OUTDOOR SOUND REFLECTION

ONTARIO MINISTRY OF THE ENVIRONMENT

ENVIRONMENTAL APPROVALS AND LAND USE PLANNING BRANCH

DECEMBER 1986

ADJUSTMENT PROCEDURES FOR OUTDOOR SOUND REFLECTION

1.0 Introduction

Recently the Noise Assessment Unit released a road traffic prediction model titled "Guidelines for Road Traffic Noise Assessment". The prediction scheme is to be used to evaluate the traffic noise level for the purpose of land use assessment, approvals of new installations and abatement. Adjustment for distance, ground absorption, dense woods and barriers were also presented in the document. The effect of sound reflections from facades which depend on site-specific conditions were left to be included in appropriate sections in the acoustic manuals currently under preparation by the Ministry staff.

To aid consultants who are working on noise assessment of land use evaluations prior to the issue of the acoustic manuals, an early edition of the procedure for consideration of sound reflection is issued in the following brief paper.

2.0 Background

Most of the procedures that are currently in use by the Ministry assume the prediction or the measurement of sound in sites, where there are no hard reflecting surfaces. The major application or objective of the Ministry's procedure is to estimate the outdoor sound level, either by prediction or by measurement. However, in the majority of the cases, where sound is predicted near an exterior

surface (building facades for instance) the sound level will vary considerably due to wavelike character of sounds. A proper definition of the "Outdoor sound level near exterior facades" is required. An appropriate procedure must also be recommended.

A number of researchers have studied the effect of reflection from exterior surfaces on the outdoor noise levels. References 1, 2, and 3 report results of measurements conducted to investigate proper measurement procedure that would take into account the influence of exterior surfaces. Reference 4 is an A.S.T.M. Standard released in 1984 which synthesizes all the available methods into a single standard. Reference 5 summarizes the insulation capabilities of exterior surfaces when the incident sound is not perpendicular to the surface. Reference 6 discusses procedures that can be applied when predicting outdoor noise levels.

Only a sample list of available literature has been presented. Even though the bibliography is not exhaustive, the quoted references address the main concerns in sufficient depth and are adequate to formulate the procedures that are required.

3.0 Discussion

There are three main areas of concern for the Ministry where the evaluation of the outdoor noise level is of primary interest, namely:

a) Land Use assessment
b) Approvals of new installations
c) Abatement

The determination of outside noise levels for abatement and approvals is usually obtained through a measurement program. The measurements are conducted on-site where the exterior surface already exists. The measurement procedures outlined in many of the Ministry publications, if properly executed, would include the effect of reflection and no additional adjustments are necessary.

In Land Use assessment, most of the currently available procedures use well established theoretical prediction schemes to evaluate the outdoor sound level. The calculations predict a "free-field" sound level at receptor locations where the proposed structures are to be constructed. However, the prediction methods have made no allowance for reflections from the building facade.

The guideline procedures presented here apply to noise prediction techniques designed for the calculation of free-field (outdoor) sound levels and consists of adjustment factors to be applied to the predicted sound level.

4.0 Guideline Procedures

The National Research Council of Canada publication B.P.N. 56 (Reference 6) "Controlling Sound Transmission into Buildings" summarizes the measurement results into applicable guidelines. The above reference has been used as a basis for the adjustments present here. For detailed description of the method and the rationale for the procedures, refer to Quirt (6).

The three areas of concern where the adjustment to "free-field level" applies are as follows:

a) Outdoor living areas:

The sound level at outdoor living areas is usually estimated during daytime hours. The receiver location is 3 metres from a building facade and 1.5 metres above ground level.

b) Near building facades:

The sound level outside the bedroom window during night time hours is evaluated. For a single family dwelling the receiver location is usually about 4.5 metres above the ground level, and just outside the window.

c) Amount of sound insulation required:

When the outside level exceeds a certain limit, exterior building components must be properly specified, taking into account the required amount of insulation needed.

The applicable methods to be used in each of the above situations are given below.

4.1 Level in Outdoor Living Areas

The usual practice in land use planning is to estimate the outdoor living area noise level (L_{eq}, dBA) during the daytime hours at 3 metres away from the building facade. The prediction methods calculate "the free-field" sound level. To account for the reflections from the building facade, <u>2 dB</u> adjustments should be added to the predicted "free-field" outdoor sound level.

Note:

1. The above adjustment is also valid for corner lots even when there is an acoustic fence parallel to the noise source, and the fence has a wrap-around the property line. (See Figure 1). Municipally approved fences are not very high, and the reflections from the fence are minimal.

2. If the outdoor living area is located on the shielded side (away from the noise source) of the building facade, no extra adjustment is required.

4.2 Level Near Building Facades

In addition to compliance with the noise criteria at outdoor living areas, the Ministry procedures require the evaluation of outside levels near the bedroom window. The outside level would determine the proper house ventilation as well as the appropriate specifications for building components. To account for the reflections from the facade, 3 dB adjustments should be added to the predicted outside "free-field" sound level near the building facades.

4.3 Sound Insulation Requirements

The choice of exterior building components satisfying the Building Code requirement is adequate in most instances. However, if the outside noise level close to the facade, particularly at second storey elevations, exceeds the criteria, the building components have to be designed to provide adequate sound insulation. The required amount of sound insulation is determined by the AIF (Acoustic Installation Factor) number. AIF is a composite number developed by the National Research Council of Canada,

which is determined among others by the STC (Sound Transmission Class) of the building component. The STC of the wall, window, roof or door is usually determined by laboratory methods where the incident sound field is diffused. Such a sound field is commonly denoted as Random Incident Field. In some instances the sound field is incident only along a narrow range of angles and the transmission loss value decreases. An example is that of an exterior wall of a single family dwelling which is perpendicular to a roadway or a railway track (e.g. exterior surface 2 in Figure 1). The required AIF values in this case must be adjusted accordingly. The proper adjustment values are given in Table 1.

5.0 Conclusions

A set of guideline procedures was presented to account for the reflection from building facades. The reduction of the transmission loss properties due to the acute angles of sound incidence was also discussed, and proper adjustment factors were presented as part of the procedures.

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3.0 Hall, F.L. and Bechrakis, N. "The Effect of the Angle of Incidence on Residential Acoustical Insulation" Noise Control Engineering Journal, Volume 22, No. 2, 1984, pp 42-47.

4.0 Standard Guide for "Field Measurement of Airborne Sound Insulation of Building Facades and Facade Elements". A.S.T.M. Standard E966-84.

5.0 Sabine H.J., Lacher, M.B., Flynn, D.R., and Cluindry, T.L., "Acoustical and Thermal Performance of Exterior Residential Walls, Doors and Windows". National Bureau of Standards, Washington D.C., 1975.

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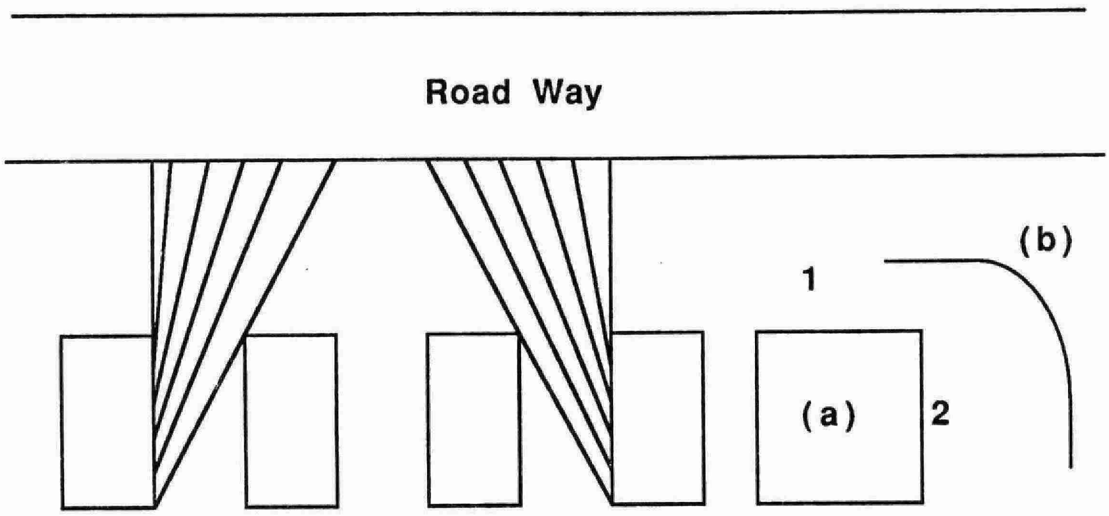


(a) Corner Lot

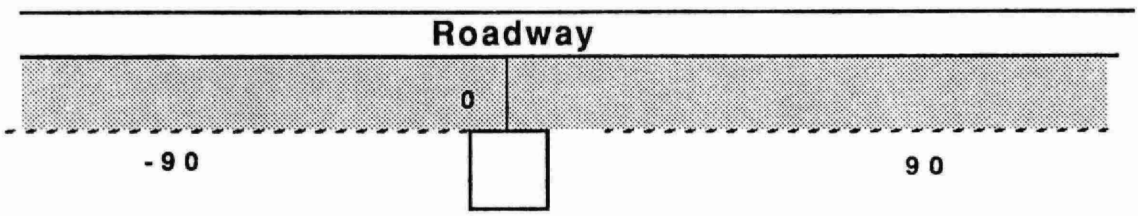
1,2 : Exterior Surfaces

(b) Wrap around Acoustic Fence

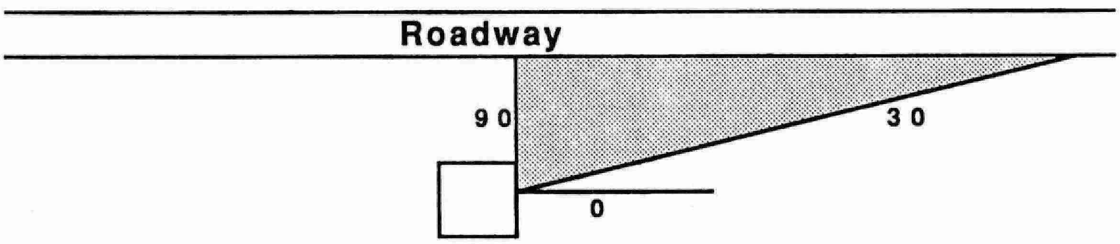
Figure 1. Sketch of a corner lot exposed to the road

Angles at which sound arrives (0=perpendicular to surface)	Correction
60 to 90 degrees	3
40 to 90 degrees	2
30 to 90 degrees	1
0 to 90 degrees	0

Note: The angles are defined by the angle between the perpendicular to the affected surface and the angle (or range of angles) of the sound incidence as shown below.



Angle: 0 to 90 degrees



Angle: 30 to 90 degrees

Table 1. Correction for source geometry to be added to the required AIF. (Source: Reference 6.)

(The angular range best describing the dominant noise source should be used)